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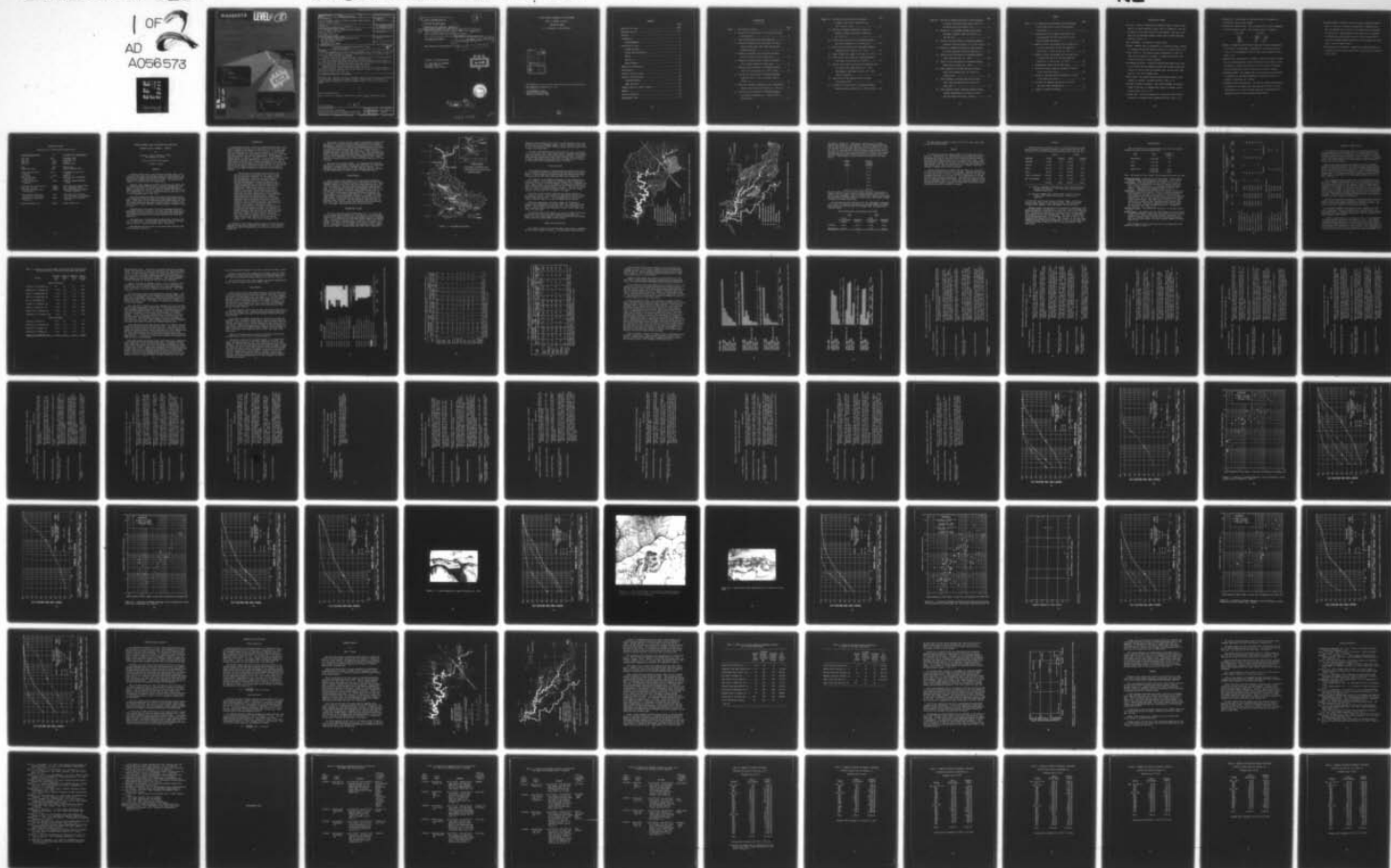
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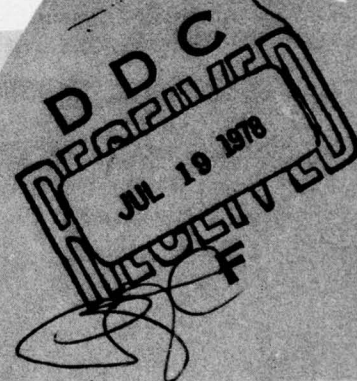
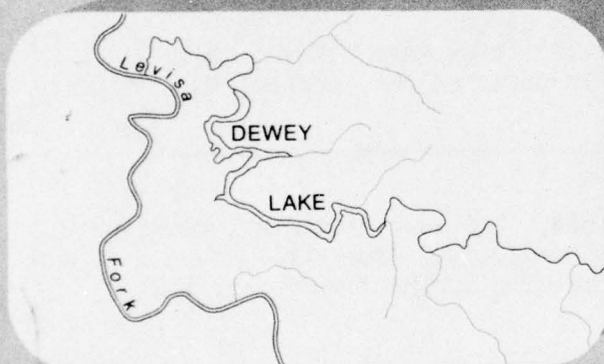
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FLUVIAL SEDIMENT STUDY OF
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KENTUCKY-VIRGINIA

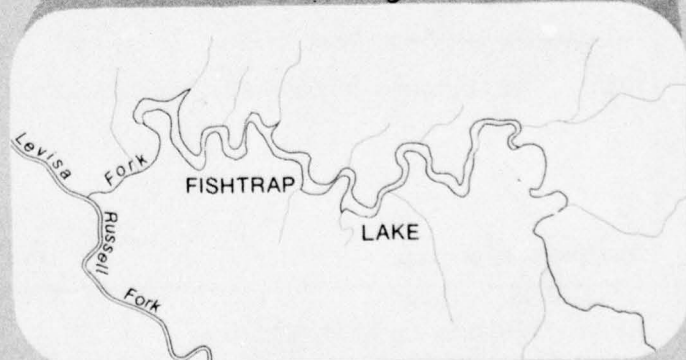
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Water-Resources Investigations 77-123

Prepared in cooperation with
U.S. ARMY CORPS OF ENGINEERS
Huntington District
Huntington, West Virginia



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FLUVIAL SEDIMENT STUDY OF
FISHTRAP AND DEWEY LAKES
DRAINAGE BASINS, KENTUCKY - VIRGINIA

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By William F. Curtis, Russell F. Flint, ~~and~~ Frederick H. George

With a section on water quality by John F. Santos

U.S. GEOLOGICAL SURVEY,
Louisville, Ky

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Water-Resources Investigations 77-123

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DEFINITION OF TERMS

Acre-foot. A unit for measuring the volume of water, is equal to the quantity of water required to cover 1 acre to a depth of 1 foot and is equal to 43,560 cubic feet or 325,851 gallons. The term is commonly used in measuring volumes of water used or stored (Langbein and Iseri, 1960, p. 4).

Bed or Streambed. The bottom of a water course.

Bedload. Sediment that is transported in a stream by rolling, sliding, or skipping along the bed and very close to it, (Colby, 1963, p. VI).

Cfs-day ($\text{ft}^3/\text{s}\cdot\text{d}$). The volume of water represented by a flow of 1 cubic foot per second for 24 hours. It equals 86,400 cubic feet, 1.983471 acre-feet, or 646,317 gallons.

Data-comparison period. Period for comparing data among study areas. In this report the data-comparison period for Fishtrap study areas consists of the 1974 and 1975 calendar years, and for Dewey study areas it is the 1975 calendar year.

Direct runoff. The runoff entering stream channels promptly after rainfall or snowmelt, (Langbein and Iseri, 1960, p. 4).

Discharge of water or sediment. Time rate of movement of volume or weight of the water or sediment past a point or through a cross-section (Colby, 1963, p. VI).

Drainage area. That area, measured in a horizontal plane, which is enclosed by a drainage divide (Langbein and Iseri, 1960, p. 8).

Particle size. The diameter, in millimeters (mm), of sediment determined by sieve or other methods.

Particle-size classification. That classification of sizes recommended by Lane and others, (1947). The classification is as follows:

Class name	Size (mm)
Clay	0.00024 - 0.004
Silt	.004 - .062
Sand	.062 - 2.0
Gravel	2.0 - 64.0

Sediment. Fragmental material that originates from the disintegration of rock and is transported by, suspended in, or deposited by water or air, or is accumulated in beds by other natural agencies (Colby, 1963, p. VI).

Sediment yield. The quantity of sediment, expressed in units of weight per unit of drainage area or unit of weight per unit volume of flow, that passes a stream cross-section in a unit of time; for example, tons per square mile per year or tons per acre-foot of runoff.

Suspended sediment. The sediment that at any given time is maintained in suspension by the upward components of turbulent currents or sediment in suspension as a colloid.

Suspended-sediment concentration. The velocity-weighted concentration of sediment in the sampled zone (from the water surface to a point approximately 0.3 ft above the bed) expressed as milligrams of dry sediment per liter of water-sediment mixture (mg/L).

Suspended-sediment discharge. The rate at which suspended sediment passes a section of a stream or the quantity of suspended sediment, as measured by dry weight, or by volume, that is discharged in a given time. When expressed in tons per day, it is computed by multiplying water discharge in cubic feet per second (ft^3/s) times the suspended-sediment concentration in milligrams per liter (mg/L), times the factor 0.0027.

Trap efficiency of a reservoir. Proportion, usually expressed as a percentage, of the sediment inflow that is retained by the reservoir (Colby, 1963).

CONVERSION FACTORS

(English units to International System units)

<u>Multiply English units</u>	<u>by</u>	<u>To obtain Int. System units</u>
inch (in)	25.4	millimeter (mm)
inch (in)	2.54	centimeter (cm)
foot (ft)	.3048	meter (m)
mile (mi)	1.609	kilometer (km)
acre	.4047	hectare (ha)
square mile (mi ²)	2.59	square kilometer (km ²)
pounds per cubic foot (lb/ft ³)	16.02	kilograms per cubic meter (kg/m ³)
ton (short)	.9072	tonne (t)
ton per acre-foot (ton/acre-ft)	736	tonne per cubic hectometer (t/hm ³)
ton per square mile (ton/mi ²)	.3503	tonne per square kilometer (t/km ²)
cubic foot per second (ft ³ /s)	.02832	cubic meter per second (m ³ /s)
acre-foot (acre-ft)	.001233	cubic hectometers (hm ³)
acre-foot per square mile (acre-ft/mi ²)	.000476	cubic hectometers per square kilometer (hm ³ /km ²)
cubic foot per second per square mile [(ft ³ /s)/mi ²]	.0109	cubic meter per second per square kilometer [(m ³ /s)/km ²]
cubic foot per second-day (ft ³ /s.d)	.02832	cubic meter per second-day (m ³ /s.d)
degree Fahrenheit (°F)	-32x5/9	degree Celsius (°C)

FLUVIAL SEDIMENT STUDY OF FISHTRAP AND DEWEY LAKES

DRAINAGE BASINS, KENTUCKY - VIRGINIA

By

William F. Curtis, Russell F. Flint,
and Frederick H. George

with a section on water quality

By John F. Santos

ABSTRACT

Fourteen drainage basins above Fishtrap and Dewey Lakes in the Levisa Fork and Johns Creek drainage basins of eastern Kentucky and southwestern Virginia were studied to determine sedimentation rates and origin of sediment entering the two lakes. The study basins ranged in size from 1.68 to 297 square miles.

Sediment yields ranged from 2,890 to 21,000 tons per square mile for study areas where surface-mining techniques predominated, and from 732 to 3,470 tons per square mile where underground mining methods predominated. Yields, in terms of tons per acre-foot of runoff, ranged from 2.2 to 15 for surface-mined areas, and from 0.5 to 2.7 for underground-mined study areas.

Water and sediment discharges from direct runoff during storms were compared for selected surface-mined and underground-mined study areas. Data points of two extensively surface-mined areas, one from the current project and one from a previous project in Beaver Creek basin, McCreary County, Kentucky, grouped similarly in magnitude and by season.

Disturbed areas from mining activities determined from aerial photographs reached 17 percent in one study area where extensive surface mining was being practiced. For most study areas where underground mining was practiced, percentage disturbed area was almost negligible.

Trap efficiency of Fishtrap Lake was 89 percent, and was 62 percent for Dewey Lake. Average annual deposition rates were 464 and 146 acre-feet for Fishtrap and Dewey Lakes, respectively.

The chemical quality of water in the Levisa Fork basin has been altered by man's activities.

INTRODUCTION

Fishtrap Dam and Lake, located in southcentral Pike County in the Eastern Kentucky Coal Field, was completed in 1968 by the U.S. Army Corps of Engineers, Huntington (W. Va.) District. It was designed with a seasonal pool of 1,145 acres and a capacity of 37,480 acre-feet and is operated for flood control, general recreation, fish and wild-life benefits, and low-flow augmentation. During December through March, the reservoir is held at a low-storage volume for flood control and for low-flow augmentation. The pool level is normally maintained at elevation 725. During the remainder of the year, in order to meet the requirements of low-flow augmentation, fishing and recreation, the pool is maintained at elevation 757. In the fall of 1971, a severe sediment-deposition problem in Fishtrap Lake was observed by the Corps of Engineers as described in the following excerpt:

"The severity of the problem materialized in the fall of 1971 when the drawdown of the lake to winter pool elevation was completed. At the request of the District Engineer, a field survey, participated in by representatives of the U.S. Attorney's Office, the Kentucky Department of Mines and Minerals, the Division of Reclamation, the Kentucky Water Pollution Control Commission, and the Corps of Engineers was conducted at Fishtrap Lake during the last week of January 1972. This survey covered all the mining activity on Government surface-owned lands and revealed the fact that a major source of both sedimentation and recreation degradation was the uncontrolled construction of access and haul roads. Specific causes noted were the almost total lack of drainage structures such as ditchlines and culvert pipes, the steepness of the excavated back slope, the disposal of excess cut material over the downhill slope which contributes to an unstable condition and greatly increases the possibility of slides in areas which are of their natural condition unstable, the disposal of downed brush and timber and excess cut material in the natural drainways, the lack of rock or other type base material to support the loads carried, the almost total lack of any reclamation effort, the lack of any timber-clearing plan, and the lack of an erosion-control plan." (U.S. Army Corps of Engineers, 1972, p. 2).

A resurvey of the original sediment ranges of the reservoir was completed by the Corps of Engineers in March 1972. This resurvey indicated an annual sedimentation rate of nearly seven times the design rate.

The results of these reservoir surveys caused general concern over the effects of coal mining on the stream and reservoir environment. Subsequently, the Corps of Engineers, Huntington District, asked the U.S. Geological Survey to study stream sedimentation and water quality in Levisa Fork above Fishtrap Lake, (fig. 1). Similar concerns extended the study area to the Johns Creek basin. This stream basin, located northwest of Fishtrap Lake (fig. 1) also contained active coal mining. The basin drains into Dewey Lake, a flood-control and recreation reservoir completed by the Corps of Engineers in 1950. Dewey Lake has a seasonal pool area of 1,100 acres and a capacity of 17,200 acre-feet.

The scope of the study included: (1) measuring the quantities and sources of the sediments entering each reservoir, (2) developing relations of sediment yield to upstream land-use practices, (3) determining the trap efficiency of each reservoir, and (4) determining the transferability of these results to unmeasured basins.

Acknowledgments

Lewis A. Smith, Civil Engineer, U.S. Army Corps of Engineers, Huntington District, planned the station distribution for the initial sediment network in the Levisa Fork basin above Fishtrap Lake. With very few exceptions, that distribution was adopted as the final network. Mr. Smith also provided other valuable help throughout the study, as did personnel at Fishtrap Lake at Millard, Ky., and at the Big Sandy area office of the Corps of Engineers in Pikeville, Ky. Mr. E. Brown of the Kentucky Department of Mines and Minerals provided guidance in the coal-mining statistics. Mr. Edmond M. Boggs, Commissioner, Virginia Department of Labor and Industry, took a personal interest in providing current figures of coal production in Buchanan County, Virginia. The data-collection phase was more complete due to the efforts of many local observers who collected samples, read gages, and helped keep the stations operating.

DESCRIPTION OF AREA

The Levisa Fork basin above Fishtrap Dam (fig. 1) is 40 mi long, with a maximum width of about 17 mi. The area is in the Cumberland section of the Appalachian Plateaus physiographic province, (Fenneman, 1938). This terrain typically has high, mature plateaus and mountain ridges of moderate-to-strong relief. The Levisa Fork valley, above the dam, is a steep-sided entrenchment with narrow or absent flood plains. Through most of its length, the stream has carved a channel 600 to 800 ft deep. Altitudes range from about 600 ft immediately

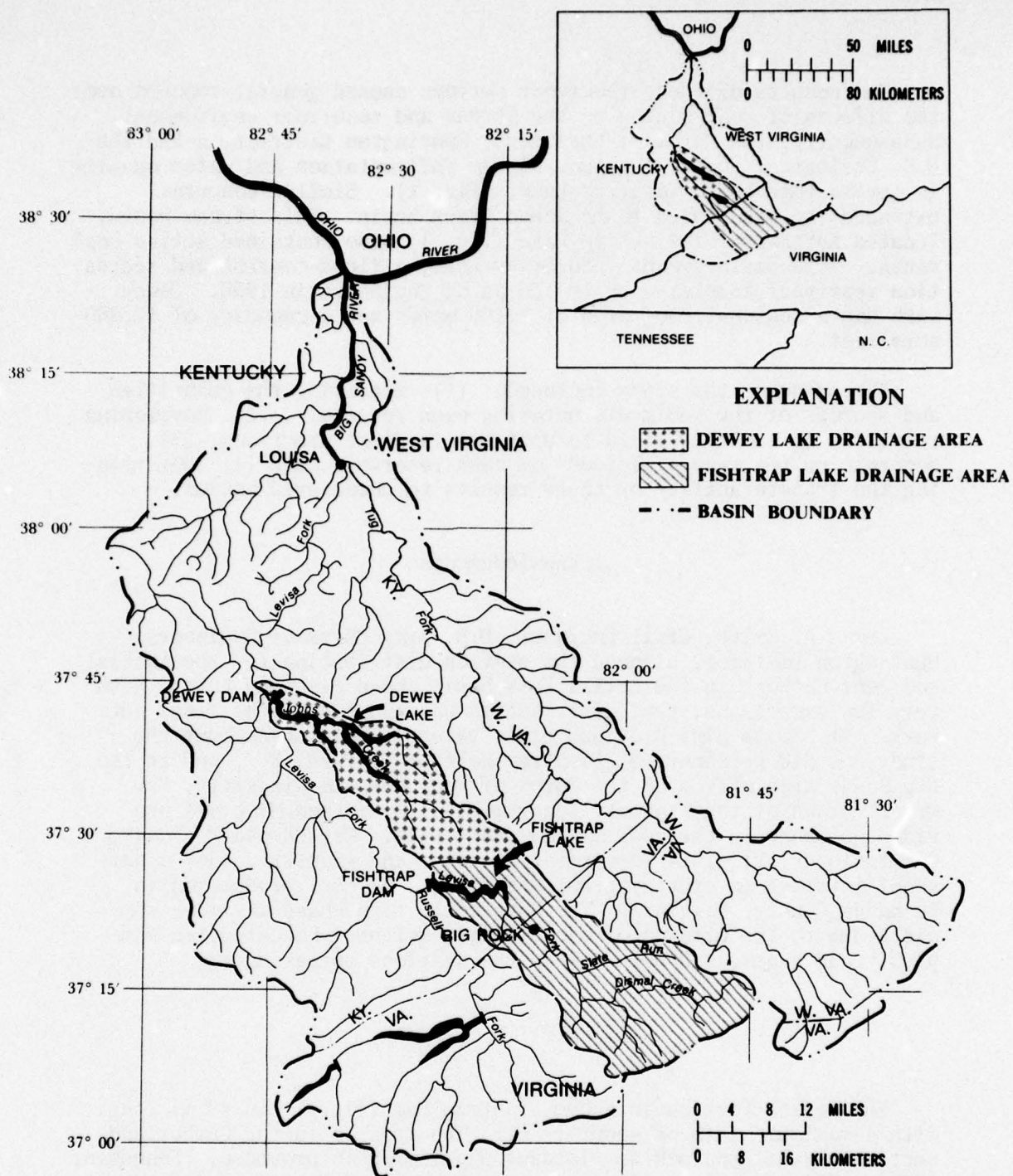


Figure 1. -- Big Sandy River basin.

downstream from Fishtrap Dam to 3,025 ft in the headwater area on the western slope of the Allegheny Ridges. Figure 2 shows the lower part of the Levisa Fork basin above Fishtrap Dam and the study areas in the vicinity of Fishtrap Lake.

The Johns Creek drainage basin above Dewey Dam (fig. 3) is tributary to the Levisa Fork. Johns Creek flows in a general northwesterly direction from the eastern part of Pike County, Kentucky. The stream winds through a narrow valley whose floor averages less than 500 ft in width. Altitudes vary from about 600 ft at Dewey Dam to 2,485 ft at Dicks Knob, on the southeastern edge of the basin.

Geology and Soils

The Breathitt Formation of Pennsylvanian age underlies the valleys and forms the hills in both the Levisa Fork and Johns Creek drainage basins. Alluvial deposits of Quaternary age form narrow flood plains along the Levisa Fork, Johns Creek and their major tributaries.

The thickness of the Breathitt Formation, in the drainage basins, exceeds 2,000 ft. The formation has alternating beds of sandstone, siltstone, and shale with lesser amounts of coal, clay, limestone, and chert. Many of the 15 to 20 coal beds in the Breathitt Formation are mined for interstate shipment and for local use. The beds are seldom over 5 ft thick. According to McFarlan (1961, p. 259) the average thickness of mined coal in Pike County is 48 inches.

The rocks in the Breathitt Formation have varying degrees of resistance to erosion. The outcrops of sandstone are the most resistant and form vertical cliffs. The associated shale is more easily eroded, especially where it is not interbedded with siltstone.

Above the flood plains, the valley slopes are 45 degrees or greater and are blanketed with residual sandy clay which grades into bedrock. The weathered rock zones are thin. The soil stands at or near its angle of repose and disturbance results in soil creep, mud flows, and landslides.

The alluvial valley-fill deposits are from 0 to about 60 ft thick, and consist of poorly sorted fine-to-medium-grained sand, silt, gravel, and clay. These deposits grade into colluvium on the steeper slopes and on the upper reaches of the streams.

Climate and Precipitation

The climate of the Levisa Fork and Johns Creek basins is temperate with the usual seasonal variations. The mean annual temperature for

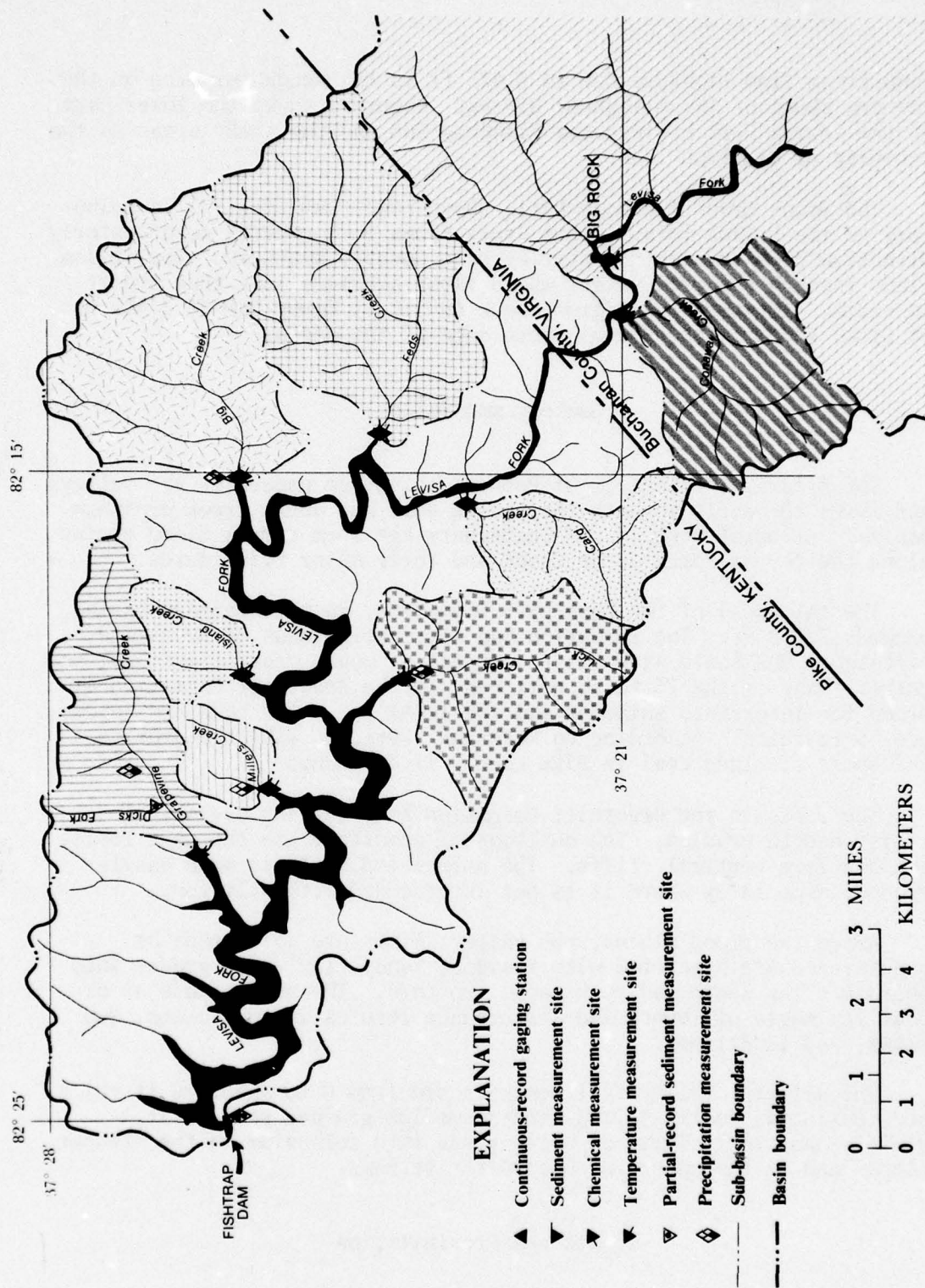


Figure 2. -- Levisa Fork drainage basin in the vicinity of Fishtrap Lake.

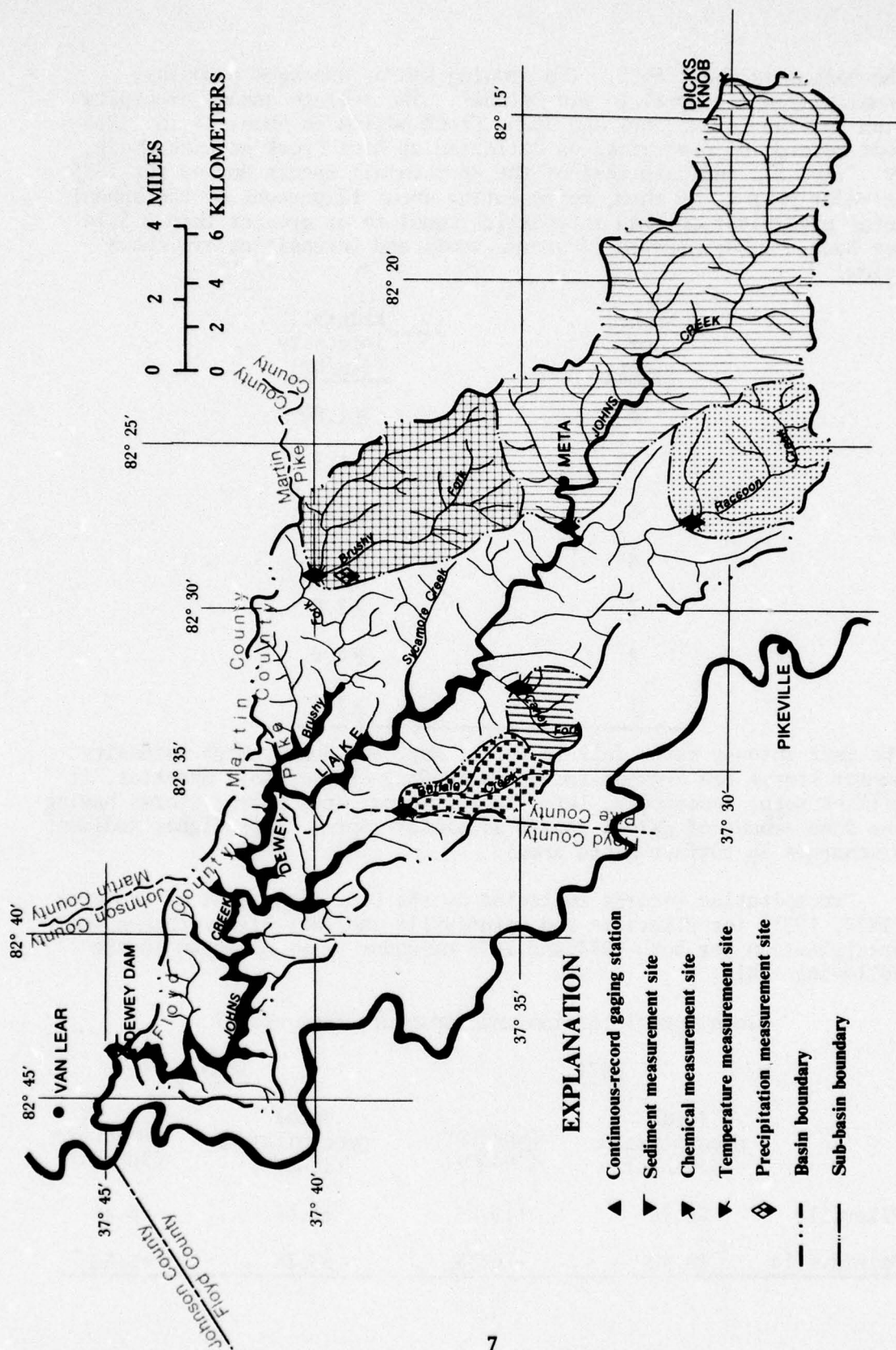


Figure 3. -- Johns Creek drainage basin above Dewey Dam.

the basins is about 56°F. The growing season averages 6 months, usually from mid-April to mid-October. The average annual precipitation for the Levisa Fork and Johns Creek basins is about 44 in. Project records of precipitation collected at Lick Creek at Lick Creek, Ky. (fig. 2), indicate that of the 88 rainfall events during the 1975 calendar year 16 of them, representing about 12 percent of the annual total precipitation, had intensities equal to or greater than 0.5 in per hour. Other numbers of storm events and intensities are shown below:

<u>Number of events</u>	<u>Rainfall intensity (in/hr)</u>
10	≥ 1.00
6	≥ 1.5
5	≥ 2.0
4	≥ 2.5
3	≥ 3.0
2	≥ 4.0
1	≥ 4.5

The most intense rains fell in April, May, and June. High-intensity summer storms are a major factor in eroding exposed soil material. It will be seen, repeatedly, later in the report that summer storms having the same amount of direct runoff as winter storms, have higher sediment discharges in surface-mined areas.

Precipitation records collected by the U.S. Department of Commerce (1974, 1975) for Pikeville and Paintsville indicate higher-than-normal precipitation for both 1974 and 1975 calendar years as shown in the following table:

Total precipitation and departure from normal

	<u>1974</u>		<u>1975</u>	
	Total precipitation (inches)	Departure (inches)	Total precipitation (inches)	Departure (inches)
Pikeville	56.44	+13.23	51.65	+8.44
Paintsville	50.40	+ 6.75	53.18	+9.53

The mean annual snowfall is about 16 in, and is only a minor part of the total precipitation.

Runoff

The inflow and outflow gaging stations for Fishtrap Lake at Big Rock, Va., and Millard, Ky., respectively, were in operation prior to and during the study as were the inflow and outflow gaging stations for Dewey Lake at Meta and Van Lear, Ky., respectively, (figs. 2 and 3). Eight additional gaging stations were installed in the Fishtrap Lake drainage area, and four were installed in the Dewey Lake Drainage area. Flow records at all these stations were used to compute runoff and sediment discharge into the two reservoirs.

Gaging-station records at Johns Creek near Meta, Ky., were used for long-term calendar-year average discharge. Average discharge over a 34-year period was $71.4 \text{ ft}^3/\text{s}$. Average discharges for 1974 and 1975 calendar years were $121 \text{ ft}^3/\text{s}$ and $111 \text{ ft}^3/\text{s}$, respectively, or 69 and 55 percent above normal, respectively. Since both 1974 and 1975 were parts of both data-comparison periods, and since both rainfall and runoff were abnormally high, it is likely that unadjusted sediment yields were higher than should be expected for most years provided all other erosion-causing factors remained in balance.

Land Use

Detailed land-use inventories were not available during the study period; however, a generalized land-use classification for 1967 for Pike County is given below along with updated figures shown for 1976:

	1967 ^{a/}		1976 ^{b/}	
<u>Land use</u>	<u>Acres</u>	<u>Percent</u>	<u>Acres</u>	<u>Percent</u>
Cropland	16,524	3.3	16,524	3.3
Pasture	13,440	2.7	13,440	2.7
Forest	425,173	84.5	400,609	79.6
Other	30,770	6.1	55,334	11.0
Total in inventory	485,907	96.6	485,907	96.6
Not in inventory	17,133	3.4	17,133	3.4
	503,040	100.0	503,040	100.0

^{a/} From U.S. Department of Agriculture, 1970, Conservation-need inventory for Kentucky: U.S. Soil Conservation Service Technical Publication.

^{b/} Personel communication, Thomas Sparks, District Conservationist, Soil Conservation Service, Pikeville, Ky., June 1977.

Of the 30,770 acres in the category labelled "other", 18,100 acres were non-farm, and 12,670 acres were in farms. Non-farm acreage includes urban, highway, water impoundment, and mining areas.

Between October 1974 and April 1975 according to computations from aerial photographs, disturbed area in the study basins (excluding area above Big Rock, Va.) increased by 926 acres (2,701 to 3,627). Most of this is attributed to the increase in mining activity as indicated by an inspection of the aerial photographs. Haul roads estimated from aerial photographs occuty, on the average, one acre in five, of the disturbed area connected with mines. This estimate is also based upon computations made from aerial photographs of four selected study areas in Levisa Fork basin, and of all five fo the study areas of Johns Creek basin.

Mining Methods

Types and intensities of mining methods used in 1973 in Eastern Kentucky are given in the following table:

<u>Type</u>	<u>Tons</u>	<u>Percent of total</u>
Underground	41,099,486	55.6
Strip	6,505,295	8.8
Auger	1,792,141	2.4
Auger-strip	24,546,598	33.2
	<u>73,943,520</u>	<u>100.0</u>

Note: For purposes of this report, the following definitions are used:

Underground mining - means any type of deep mining. (Thomas Denny, Kentucky Division of Reclamation, oral commun., July 7, 1977).

Strip mining - means the breaking of the surface soil in order to facilitate or accomplish the extraction or removal of minerals, ores, or other solid matter....., but shall not include those aspects of deep mining not having significant effect on the surface. (Kentucky Revised Statutes, Chap. 350, p. 3).

Auger mining - "Generally practiced but not restricted to hilly coal-bearing regions of the country. Utilizes a machine designed on the principle of the auger, which bores in to an exposed coal seam, conveying the coal to a storage pile or bin for loading and transporting." May be used alone or in combination with conventional surface mining. When used alone, a single cut is made sufficient to expose the coal seam and provide operating space for the machine. When used in combination with surface mining the last cut pit provides the operating space." (Bituminous Coal Research, Inc., 1974, p. 2).

Auger-strip mining - the combination referred to in the above definition.

Contour mining - the general term for surface mining in steep terrain, in which overburden is removed and the mineral or rock is mined by cutting into a sloping land surface and then "following" the mineral or bedrock along a hillside with continuous excavations being made at approximately the same elevation (Imhoff and others, 1976, p. IV).

Coal production in the study areas and its percentage by mining methods are shown in table 1.

Table 1.--Coal production and percentage by mining methods in the study areas of Levisa Fork and Johns Creek basins

Station	Total production tons			Percent of total production by mining method					
	1973	1974	1975	1973 Sur- face	Under- ground	1974 Sur- face	Under- ground	1975 Sur- face	Under- ground
Levisa Fork basin									
Levisa Fk. at Big Rock, Va. ^{1/}	-	-	-	-	-	-	-	-	-
Conaway Cr. at Conaway, Va. ^{1/}	-	-	-	-	-	-	-	-	-
Card Cr. at Mouthcard, Ky.	106,551	176,822	192,569	20	80	40	60	23	77
Feds Cr. at Fedscreek, Ky.	156,472	102,066	71,714	-	100	-	100	-	100
Big Cr. at Dunlap, Ky.	1,250,766	998,909	814,826	-	100	-	100	-	100
Island Cr. nr Phyllis, Ky.	426,279	407,937	249,256	-	100	-	100	-	100
Lick Cr. at Lick Cr., Ky.	55,945	408,378	317,300	58	42	5	95	8	92
Millers Cr. nr Phyllis, Ky.	290,246	312,679	269,236	46	54	53	47	25	75
Grapevine Cr. nr Phyllis, Ky.	27,513	24,008	10,938	-	100	-	100	-	100
Johns Creek basin									
Johns Ck. nr Meta, Ky.		1,976,828	2,227,215			14		86	
Raccoon Cr. nr Zebulon, Ky.		559,512	602,777			2		98	
Caney Fk. nr Gulnare, Ky.		94,714	541,846			100		-	
Brushy Fk. at Heenon, Ky.		982,249	719,364			88		12	
Buffalo Cr. nr Endicott, Ky.		662,999	180,616			100		-	
				Surface ^{2/}		Underground ^{2/}			

^{1/} Figures available by county only.

^{2/} Combined percentages for 1974 and 1975.

METHODS OF INVESTIGATION

To determine the quantity and sources of sediment entering Fish-trap and Dewey Lakes, 16 sediment and 12 streamflow stations (Four streamflow stations were in operation.) were established on selected streams draining into the two reservoirs (figs. 2 and 3). As an aid in the physical description of the study areas, drainage area, length, width, and stream gradient for all the stations except the outflow stations are given in table 2.

Records of stream discharge and manually collected suspended-sediment discharge measurements were obtained using standard methods of the U.S. Geological Survey. These are described in Buchanan and Somers (1969) and in Guy and Norman (1970). PS-69 pumping samplers were utilized at several of the sediment stations to collect samples automatically in the absence of project personnel and observers. The PS-69 sampler is described in the Inter-Agency catalog (F.I.A.S.P., 1976, p. 34-36).

Daily suspended-sediment samples were collected manually to compare their sediment concentrations with those collected by the PS-69. In general, concentrations of the manually collected samples agreed satisfactorily with those of the automatic pumping (PS-69) samplers. Gradients of the streams in the study areas (table 2) are quite high compared to, for example, the Ohio River which has an average gradient of less than 0.5 ft/mi. The turbulence resulting from the high gradients and rough streambeds probably suspended most of the materials in transport. Therefore, the suspended-sediment samples were assumed to represent the total sediment in transport.

Surveys of the deposited sediment in Fishtrap and Dewey Lakes were made by the U.S. Army Corps of Engineers, Huntington District. The volume of deposited sediment based on these surveys, is used to compute overall basin sediment yield and trap efficiency.

Water-quality samples were collected every 2 months at all stations. Field observations included pH, specific conductance, and water temperature. Laboratory analyses were made for silica, calcium, magnesium, potassium, carbonate, alkalinity, sulfate, chloride, fluoride, hardness, and turbidity.

Sediment concentration in milligrams per liter, was determined by laboratory methods described by Guy (1969, p. 11-13). The sediment concentrations were plotted on the gage-height chart, and a smooth curve drawn through the points. From the curves, daily mean values of concentration were determined for each station. Daily mean values of water discharge, in cubic feet per second (ft^3/s), were computed using a rating curve and the daily mean gage-height values determined from

Table 2.--Drainage area, basin length, basin width, and stream gradient for each study area in Levisa Fork and Johns Creek basins

Station	Drainage area mi ²	Length of basin mi	Width of basin mi	Stream gradient ft/mi
Levisa Fork basin				
Levisa Fk. at Big Rock, Va.	297	28	11	102
Conaway Cr. at Conaway, Va.	7.40	3.0	2.2	292
Card Cr. at Mouthcard, Ky.	4.18	2.8	1.4	296
Feds Cr. at Fedscreek, Ky.	11.6	3.6	2.8	283
Big Cr. at Dunlap, Ky.	9.55	4.0	3.0	345
Island Cr. nr Phyllis, Ky.	2.42	1.7	1.3	468
Lick Cr. at Lick Cr., Ky.	6.70	3.0	2.0	399
Millers Cr. nr Phyllis, Ky.	1.68	1.3	1.1	586
Grapevine Cr. nr Phyllis, Ky.	6.20	5.0	1.2	234
Johns Creek basin				
Johns Cr. nr Meta, Ky.	56.3	14	4.0	78
Raccoon Cr. nr Zebulon, Ky.	14.8	5.0	4.5	205
Caney Fk. nr Gulnare, Ky.	3.74	2.5	1.5	317
Brushy Fk. at Heenon, Ky.	20.4	6.5	3.0	127
Buffalo Cr. nr Endicott, Ky.	6.21	6.0	1.1	129

the gage-height trace. The product of the daily mean water discharge (ft^3/s) and concentration (mg/L) was multiplied by a conversion factor (0.0027) to obtain the daily sediment discharge (Porterfield, 1972, p. 19-20). On days of rapidly changing flow conditions, the graphs of gage-height and concentration were subdivided, and sediment discharges were computed for the subdivided increments. The total suspended-sediment discharge for the day was the sum of the increments.

Analyses were made to determine particle sizes of sediments being transported. These determinations consisted of sand separations by sieving, analysis of selected samples by the sieve-bottom withdrawal tube, sieve-pipet, and visual-accumulation tube methods. (Guy, 1969, p. 18-47).

Coal-separation analyses were performed on selected samples. This analysis is a modification of the Krumbein and Pettijohn (1938) procedure, and was developed at the U.S. Geological Survey water resources laboratory at Harrisburg, Pennsylvania (Oral and written commun., J. R. Ritter, and others, 1975). The results are expressed as a percentage of coal in the sample.

Data from three recording rain gages installed by project personnel near selected stream-gaging stations (fig. 2) were used to assist in defining sediment-concentration curves and for estimating periods of missing flow and sediment records. An excellent graphic precipitation record was collected at Lick Creek by local observer, Mr. Keither Williams. It was used for the determination of frequency of various rainfall intensities mentioned earlier in the section, "Climate and Precipitation". Non-recording rain gages at other stream-gaging stations were read once a day. These readings were also used in computing the records for stream discharge and suspended-sediment load.

Aerial photographs were taken during flights over Fishtrap Lake and Dewey Lake basins in October 1974 and April 1975. The purpose of these flights was to photograph the surface conditions of the two basins. Percentage disturbance caused by mining operations were later computed from the aerial photographs at the Gulf Coast Hydrosience Center, Bay St. Louis, Miss., by means of a video image processing device called an image analyzer. It was used to provide area readouts of disturbed areas shown on the aerial photographs.

Water and sediment discharges during storm periods were computed for direct runoff for several selected study areas. The purpose in these storm studies was to learn how water and sediment discharge from storm runoff varied seasonally, and to note likenesses and differences within a single area as well as among areas undergoing various mining practices. Another objective was to determine the possibility of transferability of results. Data were also compared between study areas of the current project with those of the "benchmark" Beaver Creek study which was conducted by the U.S. Geological Survey and other Federal and State agen-

cies in southeastern Kentucky in the 1950's (Collier and others, 1964).

Reservoir trap-efficiency computations were made using U.S. Corps of Engineers sediment-deposition figures for Fishtrap and Dewey Reservoirs and using sediment-discharge figures at the outflow stations.

The trap-efficiency values were compared with values obtained from Brune's capacity-inflow (C/I) curves (Brune, 1953).

DATA ANALYSIS

Daily records of water and sediment discharge from the study areas in the Levisa Fork basin were begun at different times during the period, August 1973 and August 1974. See figure 4. In order to compare data for an equal time period among the study areas, the 1974 and 1975 calendar years were combined to form a "data-comparison period" for the study areas in the Levisa Fork basin. As shown in figure 4, records were not always complete for the 2-year period, and incomplete records were estimated from other parts of the same record or from records at nearby stations.

The data-comparison period for the Johns Creek study areas (fig. 4) was the 1975 calendar year. Complete years were chosen in both Levisa Fork and Johns Creek to provide a better seasonal balance and an unbiased record.

Daily water and sediment discharges for the project stations are published in U.S. Geological Survey report, "Water resources data for Kentucky, water year 1976". Monthly totals from which many of the conclusions were made are given in the supplementary data at the end of this report. Maximum and minimum daily values of water discharge, sediment concentration, and computed annual sediment yields are given in table 3 for Levisa Fork study areas and in table 4 for Johns Creek study areas.

Analyses of chemical-quality data are discussed for Levisa Fork and Dewey basins in the section on chemical quality.

Particle-size analyses of suspended sediment were grouped according to sediment discharge at the time of sampling. Generally, the higher the sediment discharge the lower the percentage of the finer sediments, silt and clay, and higher the percentage by weight of sands. One reason for this is that higher velocities which accompany increasing water discharges increase the capability of the flow to lift many available sand particles into suspension. Exceptions to the above rule are frequent when sediment supply is limited. "Sand break analyses," which are separations of sand from concentration samples, revealed the extreme unpredictability in the percentage of sand in concentration samples.

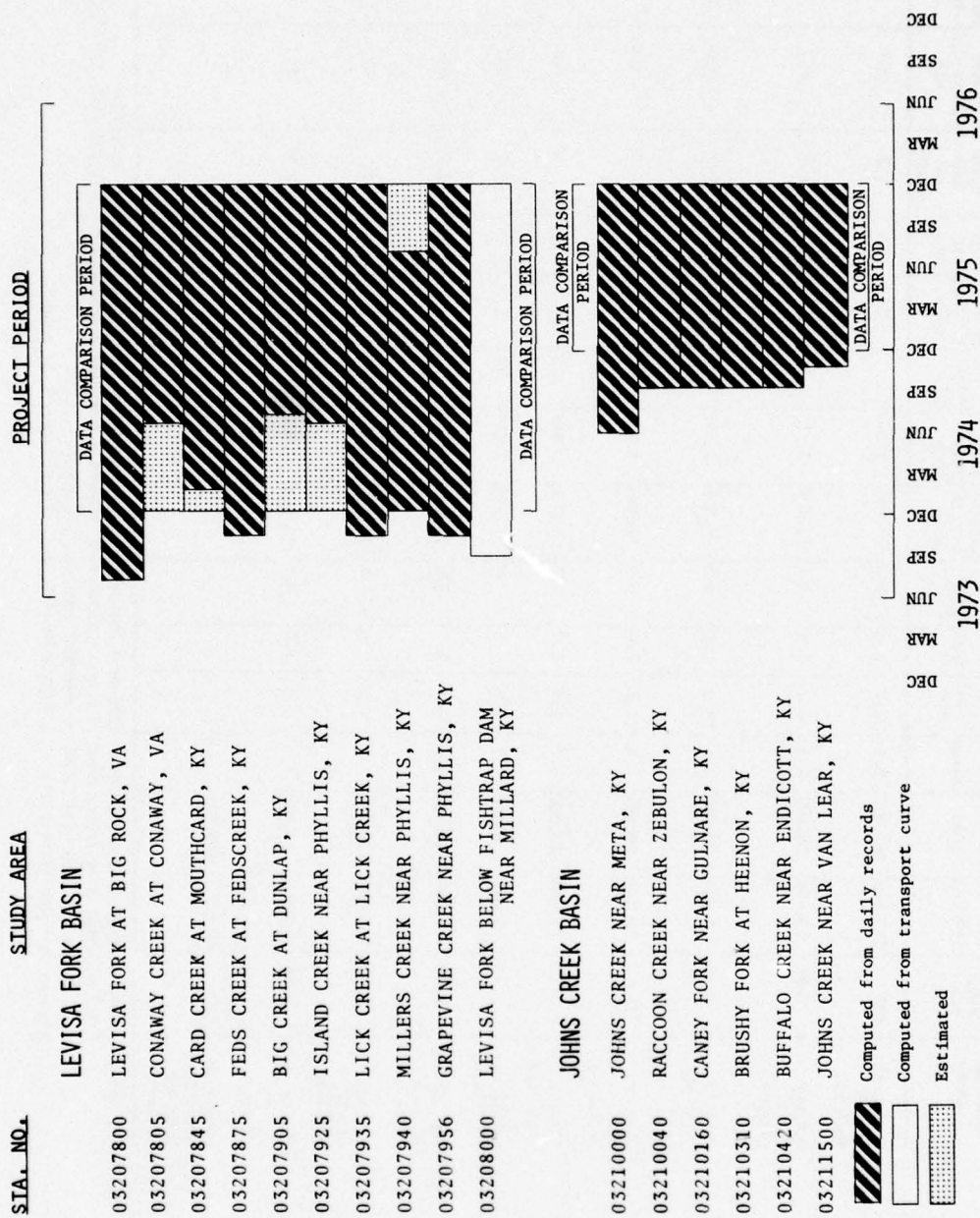


Figure 4. -- Periods of sediment-record collection for Levisa Fork and Johns Creek study areas showing data-comparison periods.

Table 3.--Summary of water and sediment data for study areas in Levisa Fork basin for the data-comparison period, Jan. 1, 1974, to Dec. 31, 1975

Station name	Drainage area mi ²	Total discharge		Percent of total at dam		Maximum daily value			Minimum daily value			Sediment yield (tons/acre-foot of runoff)		Mean annual values	
		Water ft ³ /s·d	Sediment Tons	Water	Sediment	Water ft ³ /s	Concentration mg/L	Sediment tons	Water ft ³ /s	Concentration mg/L	Sediment tons	Water (ft ³ /s·d)/mi ²	Sediment tons/mi ²		
Levisa Fk. at Big Rock Va.	297	363,896	805,893	70.1	58.8	75.8	11,600	17,700	111,000	16	2	0.14	1.1	613	1,360
Conaway Cr. at Conaway, Va.	7.40	13,000	58,000	2.5	4.2	1.9	202	12,400	3,730	1.6	1	0	2.2	880	3,900
Card Cr. at Mouth-card.	4.18	6,500	52,000	1.3	3.8	1.1	340	6,350	8,550	.12	1	0	4.0	780	6,220
Feds Cr. at Feds Creek.	11.6	16,243	16,994	3.1	1.2	3.0	487	2,460	4,270	.33	2	0	.53	700	732
Big Creek at Dunlap.	9.55	19,300	19,100	3.7	1.4	2.4	177	3,690	884	.88	2	.01	.50	1,000	1,000
Island Cr. nr Phyllis.	2.42	3,800	8,800	.7	.6	.6	79	7,530	1,010	.09	1	0	1.2	800	1,800
Lick Cr. at Lick Creek.	6.70	8,787	46,488	1.7	3.4	1.7	370	12,600	6,080	.33	1	0	2.7	656	3,470
Millers Cr. nr Phyllis.	1.68	2,300	70,700	.4	5.2	.4	78	26,800	18,600	.14	2	0	15	700	21,000
Grapevine Cr. nr Phyllis.	6.20	10,026	17,359	1.9	1.3	1.6	324	5,310	2,650	.04	1	0	.87	809	1,400
Levisa Fk. below Fish-trap Dam nr Millard.	392	519,021	147,281	-	-	-	-	-	-	-	-	-	-	-	-

Note: Total water at dam, in ft³/s·d = outflow + change in storage during period = 519,021 - 518 = 517,503.
 Total sediment arriving at dam, in tons, = deposited sediment + sediment discharged = 1,223,000 + 147,000 = 1,370,000.
 Area at dam = 392 mi² (387.8 mi² = sediment contributing area).
 Average basin sediment yield = 1,770 tons/mi²/yr, or 1.3 tons/acre-ft of runoff.

Table 4.--Summary of water and sediment data for study areas in Johns Creek basin, Kentucky, for the data-comparison period Jan. 1, to Dec. 31, 1975

Station name	Drainage mi ²	Total discharge		Percent of total at dam		Maximum daily value			Minimum daily value			Sediment yield (tons/acre-foot of runoff)	Mean annual values	
		Water ft ³ /s.d	Sediment Tons	Water	Sedi- ment	Area	Water ft ³ /s	Concen- tration mg/L	Sedi- ment tons	Water ft ³ /s	Concen- tration mg/L	Sedi- ment tons	Water (ft ³ /s.d)/ mi ²	Sediment tons/ mi ²
Johns Cr. nr Meta.	56.3	40,337	125,647	27	45	27	1,600	10,800	35,500	2.6	5	0.05	717	2,430
Raccoon Cr. nr Zebulon.	14.8	9,341	17,694	6.2	6.3	7.2	474	3,020	2,470	.51	3	.03	631	1,200
Caney Fk. nr Gulnare.	3.74	2,289	10,791	1.5	3.8	1.8	122	9,770	1,580	.12	3	0	612	2,890
Brushy Fk. at Heenon.	20.4	17,726	160,287	12	57	9.9	602	19,900	10,300	1.0	10	.03	869	7,860
Buffalo Cr. nr Endicott.	6.21	5,280	50,438	3.5	18	3.0	250	5,370	6,400	.12	1	0	850	8,120
Johns Cr. nr Van Lear.	206	153,776	105,722	-	-	-	-	-	-	-	-	-	-	-

Note: Total water at dam, in ft³/s.d = outflow + change in storage during period = 153,776 - 4,306 = 149,470.
Total sediment arriving at dam, in tons = deposited sediment + sediment discharged = 175,000 + 106,000 = 281,000.
Area at dam = 206 mi² (200.8 mi² = sediment contributing area).
Average basin sediment yield = 1,400 tons/mi²/yr, and 0.95 tons/acre-ft of runoff.

Overall average annual basin sediment yield for Fishtrap Lake drainage area was 1,770 tons/mi², computed as the sum of deposited sediment and the outflow sediment discharge divided by 387.8 square miles (table 3). The corresponding annual sediment yield for Dewey Lake drainage area was 1,400 tons/mi².

Sediment yields ranged from 2,890 to 21,000 tons/mi² for study areas where surface-mining techniques predominated, and ranged from 732 to 3,470 tons/mi² where underground-mining methods predominated.

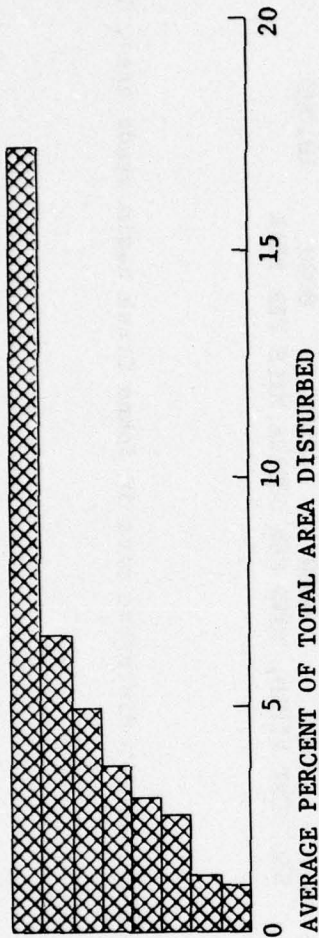
The relation of percent disturbed area with sediment yields of the study areas of Levisa Fork above Fishtrap Dam are shown in figure 5. Millers Creek has nearly three times the percentage disturbed area as the next highest study area, and a sediment yield nearly four times that of the next highest study area. However, no predictable variation is indicated for Millers Creek or the other study areas in figure 5. The lack of direct variation is even more pronounced in figure 6, a similar graph for the Johns Creek basin.

Collier and Musser (1964, p. 64) estimated a sediment yield for 1958 of 27,000 tons per square mile from the strip-mined parts of Cane Branch of Beaver Creek in McCreary County, Kentucky. This compares favorably with a sediment yield of 21,000 tons per square mile from the Millers Creek study area of Levisa Fork basin in Pike County, which has considerable area covered by auger-strip mining and haul roads. Grubb and Ryder (1972, p. 60) concluded that for the Trade-water River at Olney in the Western Kentucky Coal field, the trend in sediment load followed, in general, the fluctuations in strip-mine coal production upstream for the winter storm period of November to April. Although too short a study period existed in Caney Fork study area of Johns Creek basin in Pike County during the current project to define the relationship between sediment yield and coal production, it was shown that 23 times (0.17 tons versus 3.97 tons) as much sediment per acre-foot of water runoff and over 100 times more sediment was measured (23 tons versus 2,364 tons) in October and November of 1975 when auger-strip mining was underway as opposed to the same 2-month period a year earlier before mining was begun.

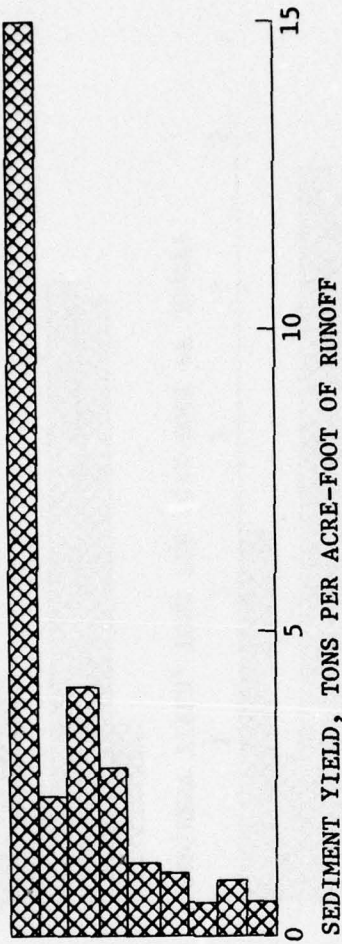
Table 5 provides a summary of sediment factors investigated during the study, and provides a data-analysis statement for each factor. Figures 7 through 25 supplement the statements presented in table 5. The stations of table 5 are arranged in downstream order.

STUDY AREA

MILLERS CREEK
CONAWAY CREEK
CARD CREEK
LICK CREEK
ISLAND CREEK
BIG CREEK
GRAPEVINE CREEK
FEDS CREEK



MILLERS CREEK
CONAWAY CREEK
CARD CREEK
LICK CREEK
ISLAND CREEK
LEVISIA FORK ABOVE BIG ROCK
BIG CREEK
GRAPEVINE CREEK
FEDS CREEK



MILLERS CREEK
CONAWAY CREEK
CARD CREEK
LICK CREEK
ISLAND CREEK
LEVISIA FORK ABOVE BIG ROCK
BIG CREEK
GRAPEVINE CREEK
FEDS CREEK

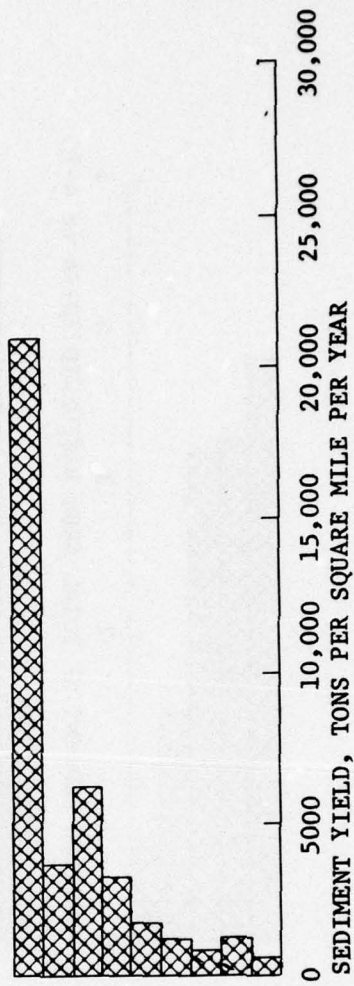
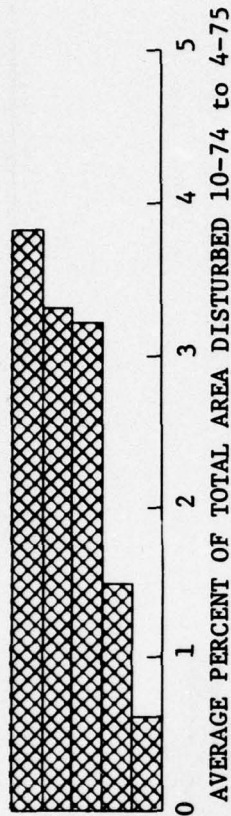


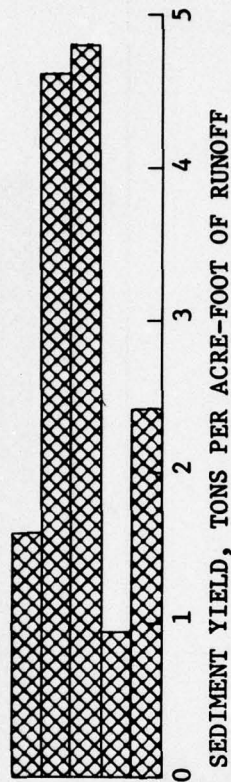
Figure 5. -- Relation of sediment yield to percent disturbed area in Levisia Fork basin study area, 1974-75.

STUDY AREA

JOHNS CREEK ABOVE META, KY
BRUSHY FORK
BUFFALO CREEK
RACCOON CREEK
CANEEY FORK



JOHNS CREEK ABOVE META, KY
BRUSHY FORK
BUFFALO CREEK
RACCOON CREEK
CANEEY FORK



JOHNS CREEK ABOVE META, KY
BRUSHY FORK
BUFFALO CREEK
RACCOON CREEK
CANEEY FORK

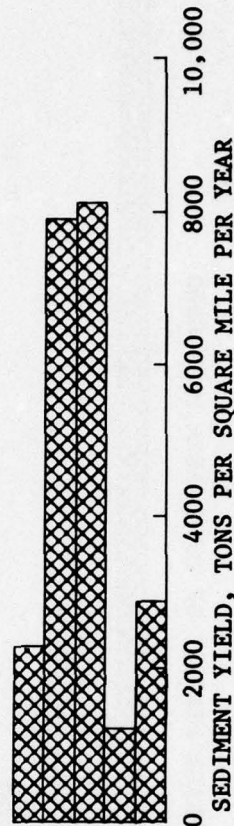


Figure 6. -- Relation of sediment yield to percent disturbed area in Johns Creek basin study area, 1975.

Table 5.--Sedimentation factors of the study areas

03207800 Levisa Fork at Big Rock, Va.

Factors investigated	Data analysis
Hydrologic importance of study area.	Comprises 76 percent of the total Fishtrap Lake drainage area, and contributes 70 percent of surface runoff, and 60 percent of sediment to Fishtrap Lake.
Coal production and type of mining.	No production figures obtained for study area alone; however, for Buchanan County, which contains all of study area, production was 14 million tons annually from 1973 to 1975. This was 40 percent of coal produced in Virginia. Eighty percent of coal was from underground mines in 1973, but this figure dropped to 72 percent for both 1974 and 1975.
Area disturbed by mining.	No determination made; however, it is assumed that disturbed area is of low order which is typical of underground mining areas.
Sediment yield and its comparison with other areas.	Suspended-sediment yield was found to be 1,360 tons per mi ² per year, and 1.1 tons per acre-ft of runoff, and was 23 percent under the average of 1,770 tons per mi ² for the entire Fishtrap Lake drainage area. Six other areas (table 5) had higher sediment yields per square mile. Five other areas had greater yield per acre-ft of runoff.
Particle-size distribution.	Selected concentration samples were divided into sand and silt plus clay. As expected a very wide range (0 to 75) percent sand existed for varying amounts of water and sediment discharge. No regularity was seen. For the 10 complete particle-size analyses, it was seen (fig. 7) that the higher the sediment discharge, the coarser the particle-size distribution.
Percentage of coal in suspended sediment.	Nine analyses indicated a range of 0 to 2 percent.

Table 5.--Sedimentation factors of the study areas--Continued

03207805 Conaway Creek at Conaway, Va.

Factors investigated

Data analysis

Hydrologic importance of study area.

Comprises less than 2 percent of the total drainage area of Fishtrap Lake, and contributes 2.5 percent of water and 4 percent of sediment to the lake.

Coal production and type of mining.

No production figures computed for the study area alone. Field observations led to conclusion that both surface and underground methods were in progress with surface techniques dominant.

Area disturbed by mining.

Benches for augering and for underground mining were observed, and overburden from construction of benches and haul roads had been pushed over hillsides creating mud slides and destroying vegetation. Disturbed area decreased from 7.4 percent of area in October 1974 to 5.4 percent in April 1975.

Sediment yield and its comparison with other study areas.

Suspended-sediment yield was 3,900 tons per mi² per year, and 2.2 tons per acre-ft of runoff. This was 220 percent of the average for the entire lake drainage area. Yield exceeded by only two other study areas in Fishtrap Lake basin.

Particle-size distribution.

Percent sand determined in selected concentration samples. Correlation of percent sand with water discharge was poor to non-existent. Extreme scatter precluded any definite conclusions. One complete analysis is given in fig. 8.

Percentage of coal in suspended sediment.

Two analyses had no coal.

Storm-sediment discharge versus storm-water discharge.

Fig. 9 indicates that for Conaway Creek a summer storm which has the same direct runoff as a winter storm will tend to have a higher sediment discharge. This relationship was also shown for Cane Branch in Collier and others, (1964, p. 59).

Table 5.--Sedimentation factors of the study areas--Continued

03207845 Card Creek at Mouthcard, Ky.

Factors investigated	Data analysis
Hydrologic importance of study area.	Makes up about 1 percent of the total drainage area of Fish-trap Lake, and contributes 1 percent of the water and 4 percent of the sediment to the lake.
Coal production and type of mining.	Production of 106,551 tons in 1973 was increased by two-thirds in 1974 and by four-fifths in 1975. Auger-strip mining accounted for 20 percent of the production in 1973, 40 percent in 1974, and 23 percent in 1975.
Area disturbed by mining.	Increased from 3.0 percent in October 1974 to 6.7 percent in April 1975.
Sediment yield and its comparison with other areas.	Suspended-sediment yield was 6,220 tons per mi ² per year, and 4 tons per acre-ft of runoff, both over three times the averages for Fishtrap Lake drainage basin. Yields exceeded by only one other study area.
Particle-size distribution.	Percent sand from sediment-concentration samples showed no correlation whatever with water discharge; however, eight complete size analyses, when grouped by instantaneous sediment discharge, (fig. 10), indicated that the higher the sediment discharge, the coarser the distribution.
Percentage of coal in suspended sediment.	Analysis of seven samples indicated a range of 0 to 7 percent with a mean of 1 percent.

Table 5.--Sedimentation factors of the study areas--Continued

03207875 Feds Creek at Feds Creek, Ky.

Factors investigated

Data analysis

Hydrologic importance of study area.

Makes up 3 percent of total area in Fishtrap Lake basin and contributes about 3 percent of runoff and about 1 percent of sediment discharge into Fishtrap Lake.

Coal production and type of mining.

Underground mining only was in use in basin during 1973-75, and accounted for 156,000 tons in 1973, 102,000 in 1974, and 72,000 in 1975. This drastic decrease in production was not typical for other areas.

Area disturbed by mining.

About 1 percent of area is disturbed which is indicative of an underground mining area.

Sediment yield and its comparison with that of other study areas.

Annual suspended-sediment yield was 732 tons/mi², and 0.53 tons per acre-ft of runoff, or 41 percent of the values for the entire Fishtrap Lake basin. Annual yield is exceeded by all other study areas of Fishtrap basin and tons per acre-ft of runoff is exceeded by seven other areas.

Particle-size distribution.

Selected concentration samples were analyzed for percentage sand, and when percent sand was plotted against water discharge, only a diverse scatter resulted. Two completed analyses, the average of which is shown in fig. 11, indicated a very coarse distribution with 56 percent sand.

Percentage of coal in suspended sediment.

Four analyses indicate a range of 0 to 6 percent with an average of less than 3 percent.

Storm-sediment discharge versus storm-water discharge.

Figure 12 shows less of a seasonal grouping of storm-sediment and storm-water discharge, typical of non-strip mined areas. This distribution agrees well with Helton Branch data shown in Collier and others (1964, p. 59). Such distribution is due to lack of available sediment for transport.

Table 5.--Sedimentation factors of the study areas--Continued

03207905 Big Creek at Dunlap, Ky.

Factors investigated	Data analysis
Hydrologic importance of study area.	Comprises 2.4 percent of total area of Fishtrap Lake drainage basin, and contributes nearly 4 percent of the runoff, and 1.4 percent of the sediment discharged into the lake.
Coal production and type of mining.	Underground mining only was practiced in the study area during 1973-75. As with Feds Creek, production dropped each year during the period. Production in 1973 was 1.25 million tons in 1974, slightly less than 1 million tons; and 1975, slightly more than 3/4 million tons.
Area disturbed by mining.	About 2 percent, typical of underground mining areas.
Sediment yield and its comparison with that of other study areas.	Annual suspended-sediment yield was 1,000 tons/mi ² , and 0.5 ton per acre-ft of runoff, and is slightly more than half the average yield for Fishtrap basin. Annual yield is exceeded by seven other study areas, and yield per acre-ft of runoff is the lowest in the basin.
Particle-size distribution.	Selected concentration samples were analyzed for percent sand, and the values were plotted against water discharge. Only a faint relationship emerged. Complete size analyses shown in figure 13 indicate that the higher the sediment discharge the coarser the distribution.
Percentage of coal in suspended sediment.	Three samples had a range of 3 to 20 percent and an average of 9 percent. This is a result of coal-washing operations immediately upstream from station, and was further evidenced by frequent "blackwater" discharges past measuring site.

Table 5.--Sedimentation factors of the study areas--Continued

03207925 Island Creek near Phyllis, Ky.

Factors investigated	Data analysis
Hydrologic importance of study area.	Makes up about 0.5 percent of area of Fishtrap basin, and contributes about the same percentage of runoff and sediment to lake.
Coal production and type of mining.	Coal production fell from about 426,000 tons in 1973 to 408,000 in 1974, and to about 250,000 in 1975. All coal was produced from underground mines, and decreasing production was typical.
Area disturbed by mining.	Less than 3 percent which was typical of underground mining areas.
Sediment yield and its comparison with other study areas.	Annual sediment yield was 1,800 tons/mi ² , which is practically equal to the average for Fishtrap Lake drainage area. Yield per acre-ft of runoff was slightly over 1 ton. Annual yield was exceeded by four other study areas as was yield per unit of runoff.
Particle-size distribution.	Selected concentration samples were analyzed for percent sand and the values plotted against instantaneous water discharge. A random scatter resulted with no correlation evident. Complete particle-size analyses shown in fig. 14, definitely indicate coarser distribution with the higher suspended-sediment load.
Percentage of coal in suspended sediment.	Analysis of six samples indicated a range of 2 to 16 percent coal with an average of about 8 percent. This probably results from coal-loading facilities immediately upstream from measuring station.

Table 5.--Sedimentation factors of the study areas--Continued

03207935 Lick Creek at Lick Creek, Ky.

Factors investigated	Data analysis
Hydrologic importance of study area.	Comprises 1.7 percent of the area of Fishtrap drainage basin, and contributes 1.7 percent of runoff and 3.4 percent of sediment to Fishtrap Lake.
Coal production and type of mining.	Production in 1973 of 56,000 tons increased by more than 600 percent in 1974 to 409,000 tons, but decreased to 317,000 in 1975. Auger-strip mining was important in 1973, producing 58 percent, but averaged only about 7 percent for 1974 and 1975.
Area disturbed by mining.	Amounted to 4.3 percent of the drainage area in October 1974, but fell to under 3 percent by April 1975. An example of disturbed area is shown in figure 15.
Sediment yield and its comparison with other study areas.	Annual suspended-sediment yield was 3,470 tons/mi ² . Yield was 2.7 tons per acre-ft of runoff. Annual yield was about double the average yield for the entire Fishtrap basin, and was exceeded by three other study areas.
Particle-size distribution.	Selected concentration samples were analyzed for percent sand and plotted against instantaneous water discharge. Only a random scatter resulted, and no relationship was evident. Complete particle-size analyses grouped by sediment discharge, shown in figure 16, indicate that the higher the sediment discharge the coarser the distribution.
Percentage of coal in suspended sediment.	Twelve analyses showed a range of 0 to 9 percent with an average of less than 2 percent.

Table 5.--Sedimentation factors of the study areas--Continued

03207940 Millers Creek near Phyllis, Ky.

Factors investigated	Data analysis
Hydrologic importance of study area.	Has about 0.5 percent of the Fishtrap drainage area, and a like percentage of runoff into the lake; however, it contributes over 5 percent of the sediment entering the lake.
Coal production and type of mining.	In 1973, 290,000 tons were mined, but increased to 313,000 tons in 1974, and fell to 269,000 in 1975. On the average, 41 percent was mined by augering.
Area disturbed by mining	Mining and haul roads produced a disturbed area of 17 percent within the study area, the highest of any study area. Fig. 17 is an aerial photograph of Millers Creek. Note the contrast in amount of disturbed area with that of Grapevine and Island Creeks. Fig. 18 also shows some of the effects of auger stripping.
Sediment yield and its comparison with other areas.	Yields were 21,000 tons per mi ² per year, and 15 tons per acre-ft of runoff. These were 12 times the average for Fishtrap basin. Most of this yield probably is from 17 percent of the study area.
Particle-size distribution.	Sand portions from several samples, expressed as percent, and plotted against water discharge showed no dependable relationship. Fig. 19 however, shows the particle-size distribution when the analyses are grouped by sediment discharge. Higher sediment discharges seem to carry large diameters of available sediment.

Table 5.--Sedimentation factors of the study areas--Continued

03207940 Millers Creek near Phyllis, Ky.--Continued

Factors investigated	Data analysis
Percentage of coal in suspended sediment.	Three samples showed negligible amounts.
Storm-sediment discharge versus storm-water discharge.	Millers Creek storms were plotted with Cane Branch storms (refer Collier and others, 1964, p. 59) to demonstrate similarity in grouping and magnitude for two surface-mined areas. Figure 20 shows a distinct grouping of storms by season.

Table 5.---Sedimentation factors of the study areas--Continued

03207965 Grapevine Creek near Phyllis, Ky.

Factors investigated	Data analysis
Hydrologic importance of study area.	Comprises less than 2 percent of the Fishtrap Lake drainage area, and contributes about 1-1/2 percent of both runoff and sediment to Fishtrap Lake. Selected as a "base" or "control" study area, it was later found that at least three other underground mining areas had lower yields.
Coal production and type of mining.	One underground mine produced about 28,000 tons in 1973, 24,000 in 1974, and fell to 11,000 tons in 1975. No appreciable surface mining was in operation during the study period.
Area disturbed by mining.	Negligible; however, construction activities produced an average of slightly over 1 percent.
Sediment yield and its comparison with other areas.	Annual suspended-sediment yield was 1,400 tons per mi ² , which was probably produced by high construction levels in the study area. This yield was about 0.8 of the average for all of Fishtrap basin. Yield was 0.87 tons per acre-ft of runoff, which was about 0.7 of the basin average.
Particle-size distribution.	Figure 21 shows an increasing percentage of sand with increasing instantaneous water discharge. This relationship is the exception among the study area. Complete particle-size analyses shown in figure 22 and grouped by instantaneous sediment discharge indicate coarser distributions occurring at the higher sediment discharges.
Percentage of coal in suspended sediment.	Four analyses had an average of less than 2 percent, and a range of 0 to 5 percent.
Storm-sediment discharge versus storm-water discharge.	Figure 23 indicates that summer-type storms tend to have higher sediment discharges than winter-type storms for equal runoff values.

Table 5.---Sedimentation factors of the study areas--Continued
03210000 Johns Creek near Meta, Ky.

Factors investigated	Data analysis
Hydrologic importance of study area.	Comprises 27 percent of the area of Dewey Lake basin, and contributes the same percentage of water to the lake, but contributes 45 percent of the sediment.
Coal production and type of mining.	Over 4 million tons were produced in 1974 and 1975. Eighty-six percent was from underground mines.
Area disturbed by mining.	An average of nearly 4 percent of the area was disturbed as indicated from aerial photographs made in October 1974 and April 1975.
Sediment yield and its comparison with other study areas.	Suspended-sediment yield was 2,230 tons per mi^2 per year, and 1.6 tons per acre-ft of runoff. The annual sediment yield and the yield per unit of runoff were exceeded by three other study areas of the Johns Creek drainage basin.
Particle-size distribution.	Selected concentration samples were analyzed for percent sand, and the figure of percent was plotted against water discharge. Only a random pattern was obtained. Complete particle-size analyses are shown in figure 24. One bed-material particle-size analysis was made, and was completely sand.

Table 5.--Sedimentation factors of the study areas--Continued

03210040 Raccoon Creek near Zebulon, Ky.

Factors investigated

Data analysis

Hydrologic importance of study area.

Comprises about 7 percent of the area of Dewey Lake drainage basin and contributes about 6 percent of the runoff and sediment entering the lake.

Coal production and type of mining.

Production was 560,000 tons in 1974 and increased to 603,000 tons in 1975. Only 2 percent was by surface-mining methods. The remainder was by underground methods.

Area disturbed by mining.

Less than 1 percent of the area in 1974 was disturbed, but about 2 percent was indicated in April 1975. This low percentage is typical of underground-mining areas.

24 Sediment yield and its comparison with other study areas.

Annual suspended-sediment yield was 1,200 tons/mi² which was about 14 percent under the average for Dewey Lake basin. Less than 1 ton of sediment per acre-ft of runoff was discharged. These were the lowest yields of any of the Dewey Lake study areas, and are typical of underground-mining areas.

Table 5.---Sedimentation factors of the study areas--Continued

03210160 Caney Fork near Gulnare, Ky.

Factors investigated	Data analysis
Hydrologic importance of study area.	Contains less than 2 percent of the Dewey Lake drainage area, and contributes about 2 percent of the runoff, and about 4 percent of the sediment to the lake.
Coal production and type of mining.	Less than 100,000 tons were mined in 1974, but over 500,000 tons were mined in 1975. All mining was by surface methods.
Area disturbed by mining.	Less than 1/2 percent of the study area in 1974 and about 1 percent in 1975 was disturbed by surface mining.
Sediment yield and its comparison with other areas.	Suspended-sediment yield was 2,890 tons per mi ² , and 2.4 tons per acre-ft of runoff. Following the beginning of surface mining in this study area in late November 1974, sediment discharge accelerated greatly. October-November of 1975 was 100 times greater than for the same period in 1974, even though the water discharge was only four times greater.
Particle-size distribution.	Only one analysis was made, and no conclusions were possible.

Table 5.--Sedimentation factors of the study areas--Continued

03210310 Brushy Fork at Heenon, Ky.

Factors investigated	Data analysis
Hydrologic importance of study area.	Comprises nearly 10 percent of Dewey Lake drainage area, and contributes 12 percent of the runoff and a disproportionate 57 percent of the sediment into Dewey Lake.
Coal production and type of mining.	Nearly 1 million tons were extracted in 1974, but production dropped to 3/4 million in 1975. Eighty-eight percent was from surface-mining operations. The remainder was from underground operations.
Area disturbed by mining.	An average of 3.3 percent for 1974 and 1975 was disturbed by mining. The percentage of area disturbed increased from 1.8 percent in 1974 to 4.8 percent in 1975, which may have resulted from mine preparation, rather than mining.
Sediment yield and its comparison with other areas.	Annual sediment yield was 7,860 tons per mi ² , and was exceeded by only one other study area in the Dewey drainage basin. This yield was over 5-1/2 times the average for the basin. Yield was 4.6 tons per acre-ft of runoff; about 5 times the basin average.
Particle-size distribution.	Percent of sand contained in selected concentration samples was plotted against instantaneous water discharge. Only a wide scatter resulted. Complete particle-size analyses shown in figure 25 are grouped by sediment discharges. One bed-material analysis consisted entirely of sand with over half of the sample of the 250 to 500 micron size.

Table 5.--Sedimentation factors of the study areas--Continued

03210420 Buffalo Creek near Endicott, Ky.

Factors investigated	Data analysis
Hydrologic importance of study area.	Comprises 3 percent of the Dewey Lake drainage area, and contributes less than 4 percent of the runoff, and a disproportionate 18 percent of the sediment to the lake.
Coal production and type of mining.	Production reached 663,000 tons in 1974, but fell to under 200,000 in 1975. All mining was by surface methods.
Area disturbed by mining.	Nearly 4 percent of area was disturbed in 1974, but under 3 percent was disturbed in 1975.
Sediment yield and its comparison with other areas.	Suspended-sediment yield exceeded 8,000 tons per mi ² , which was nearly six times the average for Dewey Lake drainage area, and the highest yield of any study area. Yield was nearly 5 tons per acre-ft of runoff, which was over five times the lake basin average.

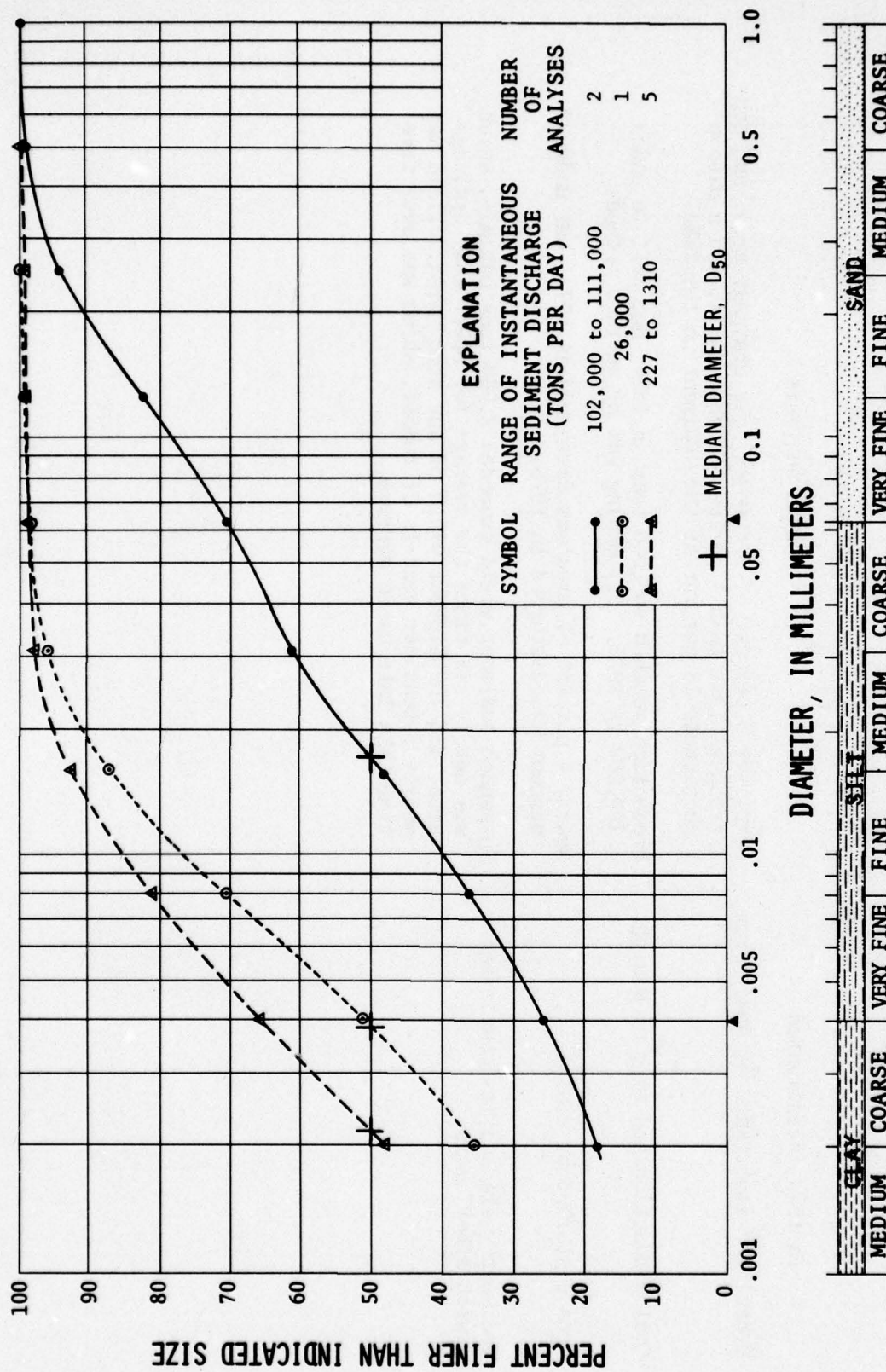


Figure 7. -- Particle-size distribution of suspended sediment, Levisa Fork at Big Rock, Va., 1973-74.

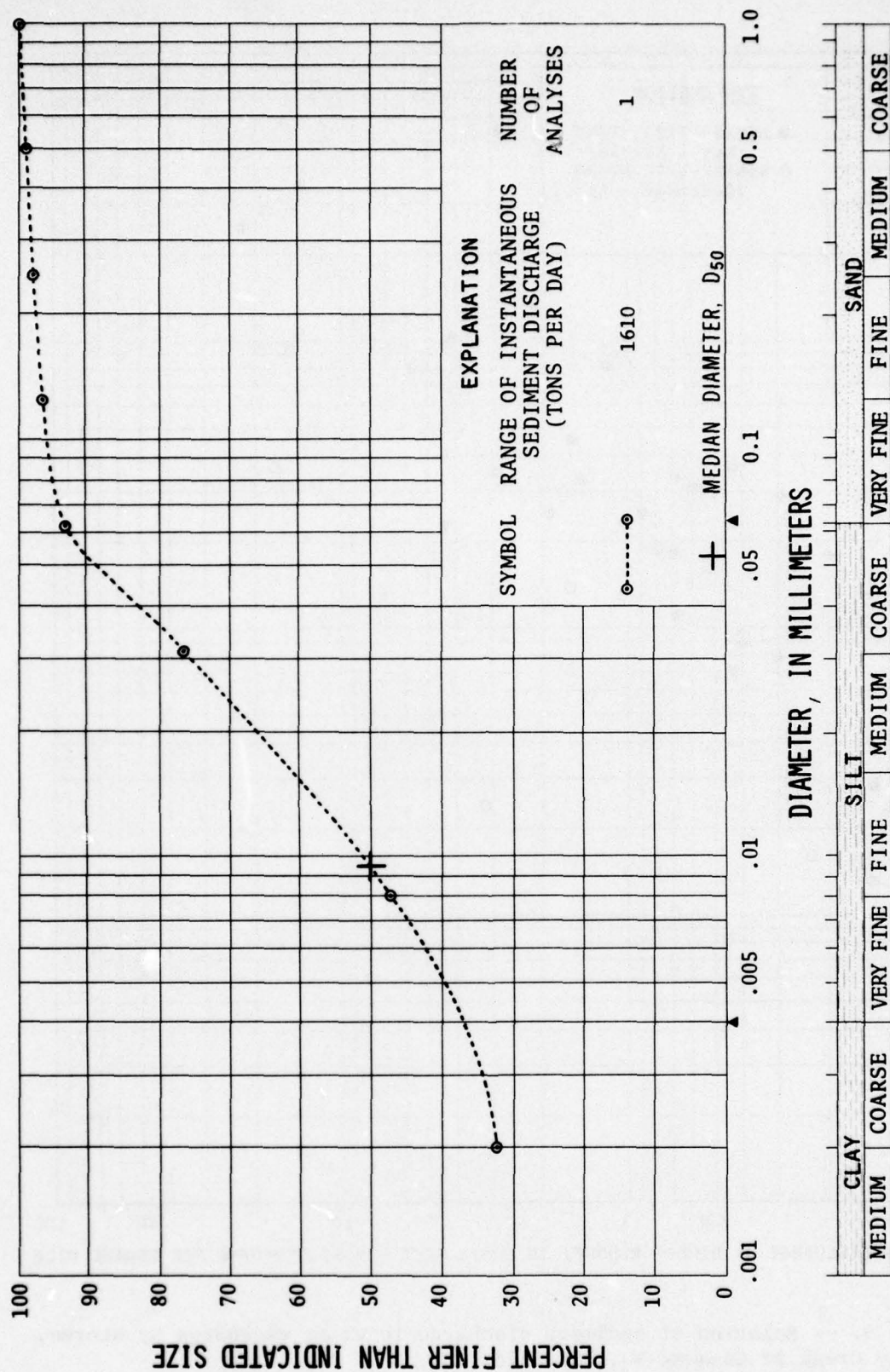


Figure 8. -- Particle-size distribution of suspended-sediment sample for February 4, 1974, Conaway Creek at Conaway, Va.

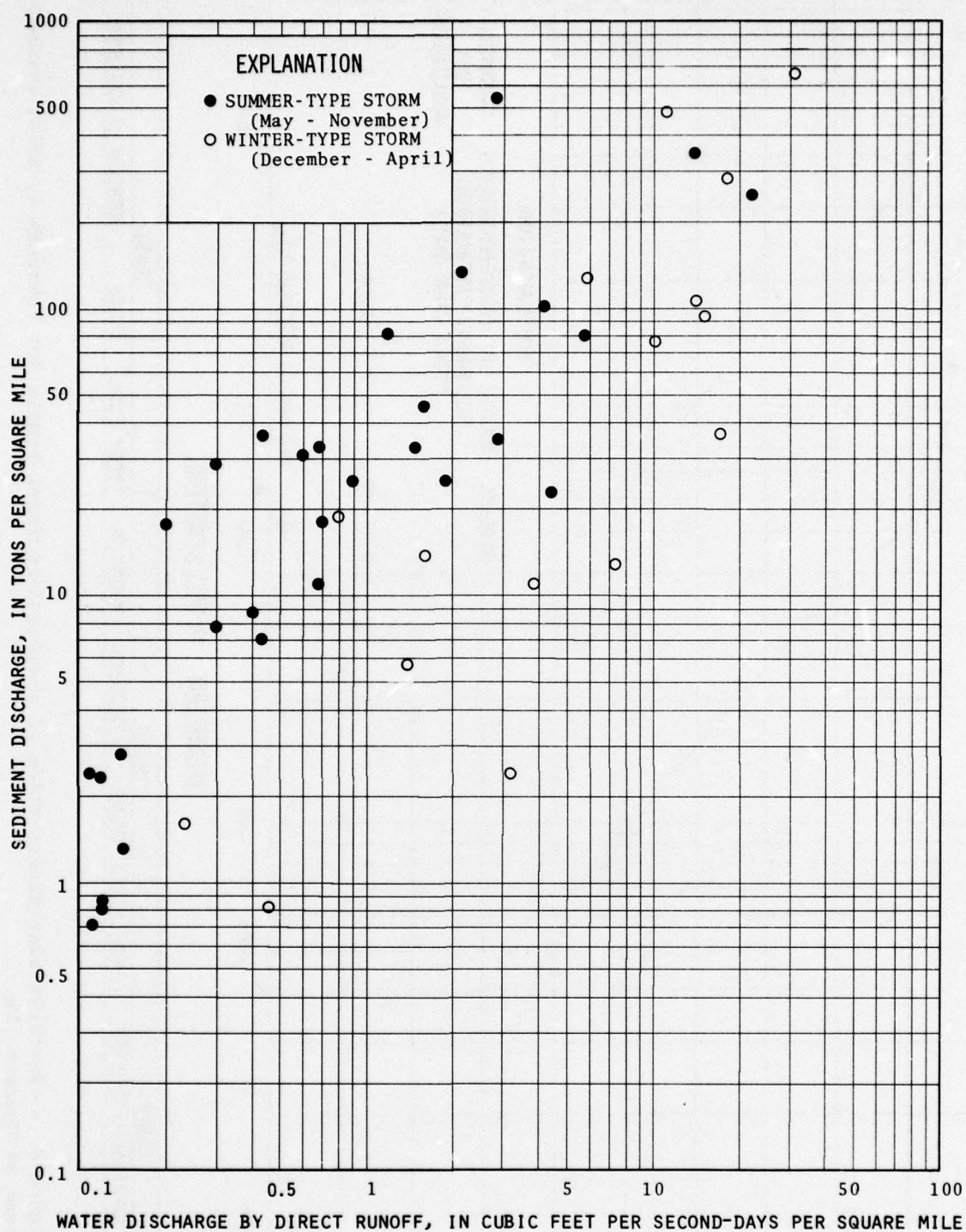


Figure 9. -- Relation of sediment discharge to water discharge by storms, Conaway Creek at Conaway Va., 1974-75.

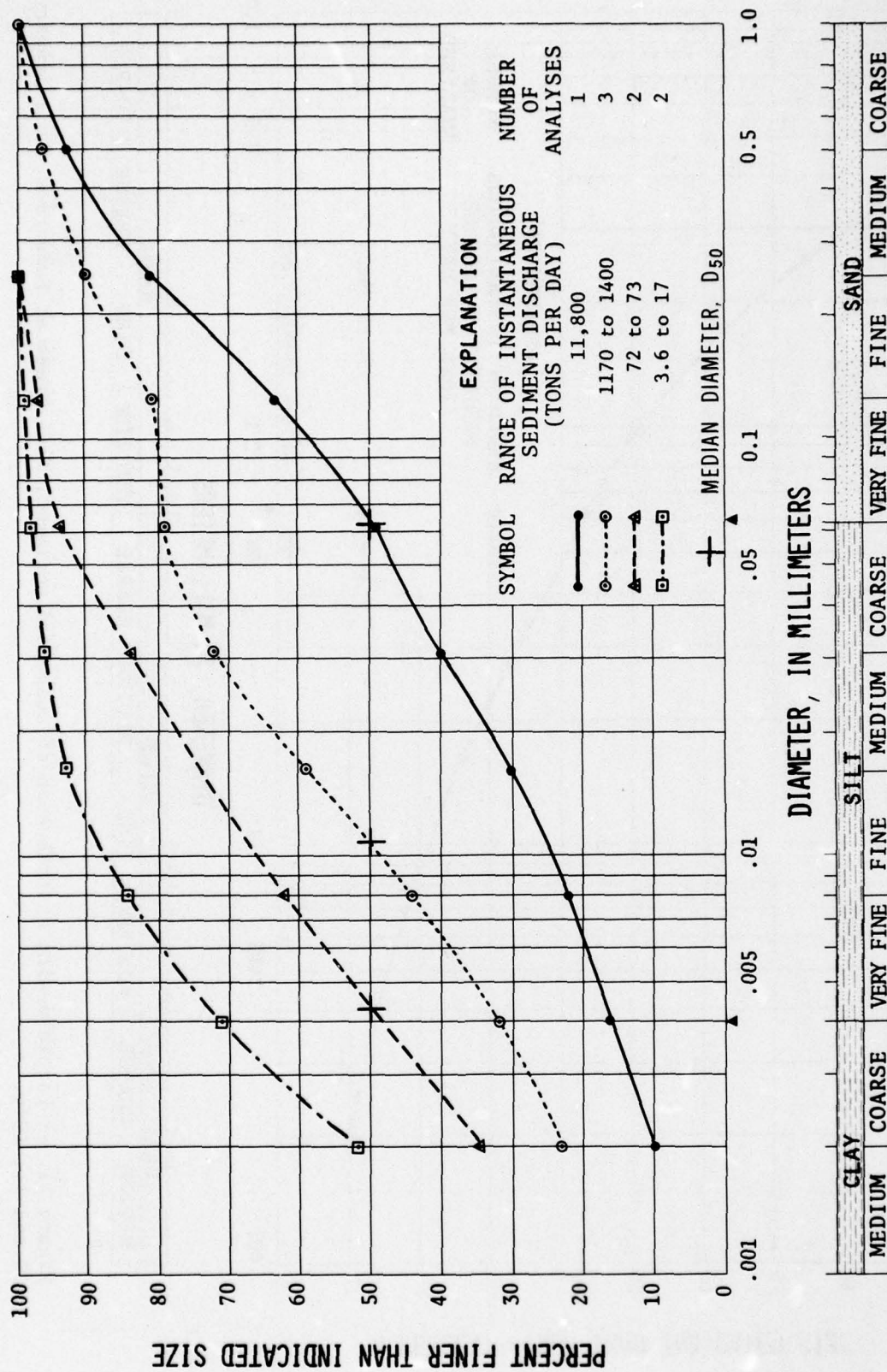


Figure 10. -- Particle-size distribution of suspended sediment, Card Creek at Mouthcard, Ky., January 1974 to February 1975.

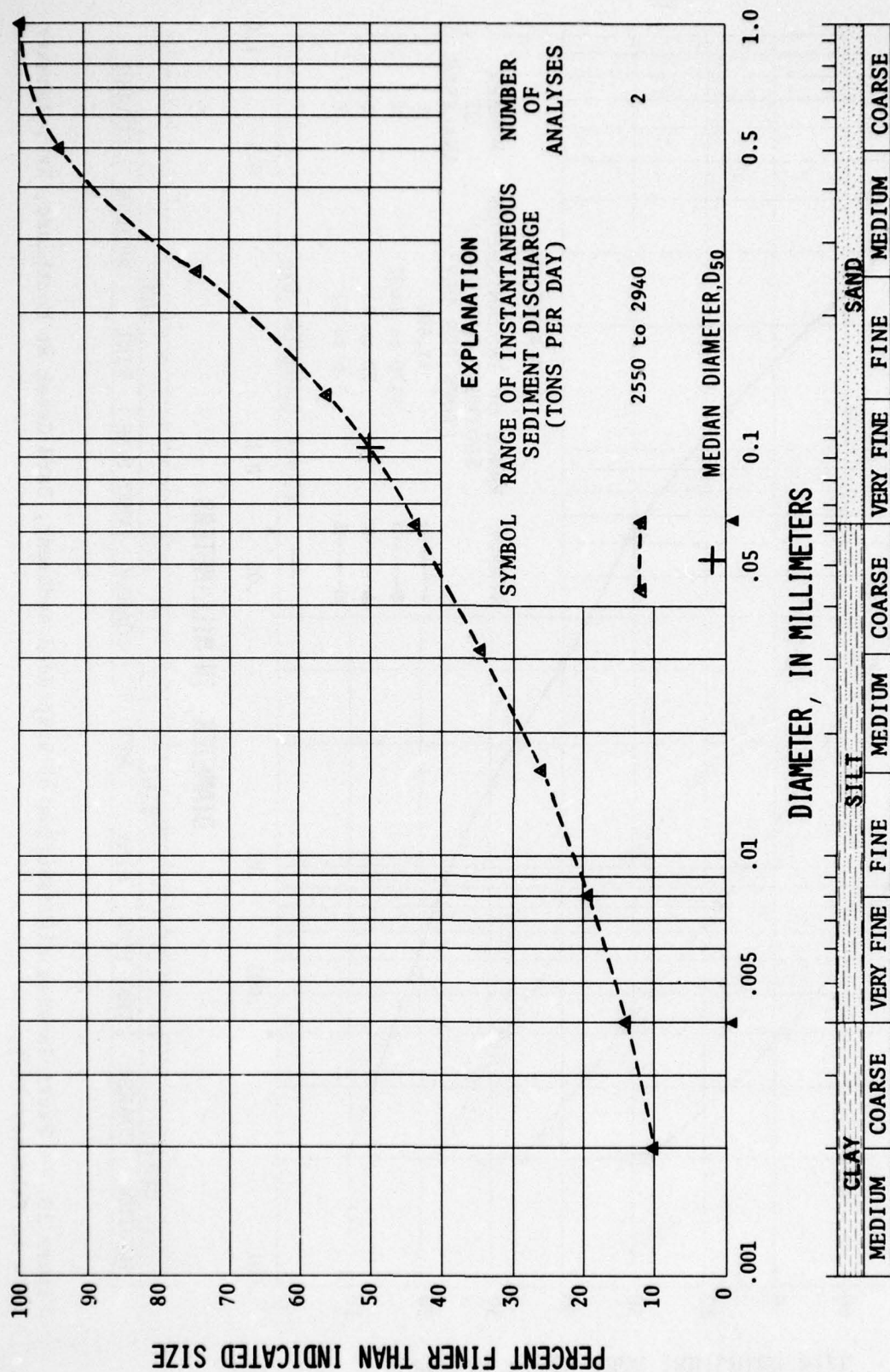


Figure 11. -- Particle-size distribution of suspended sediment, Feds Creek at Feds Creek, Ky., January 10 and 11, 1974.

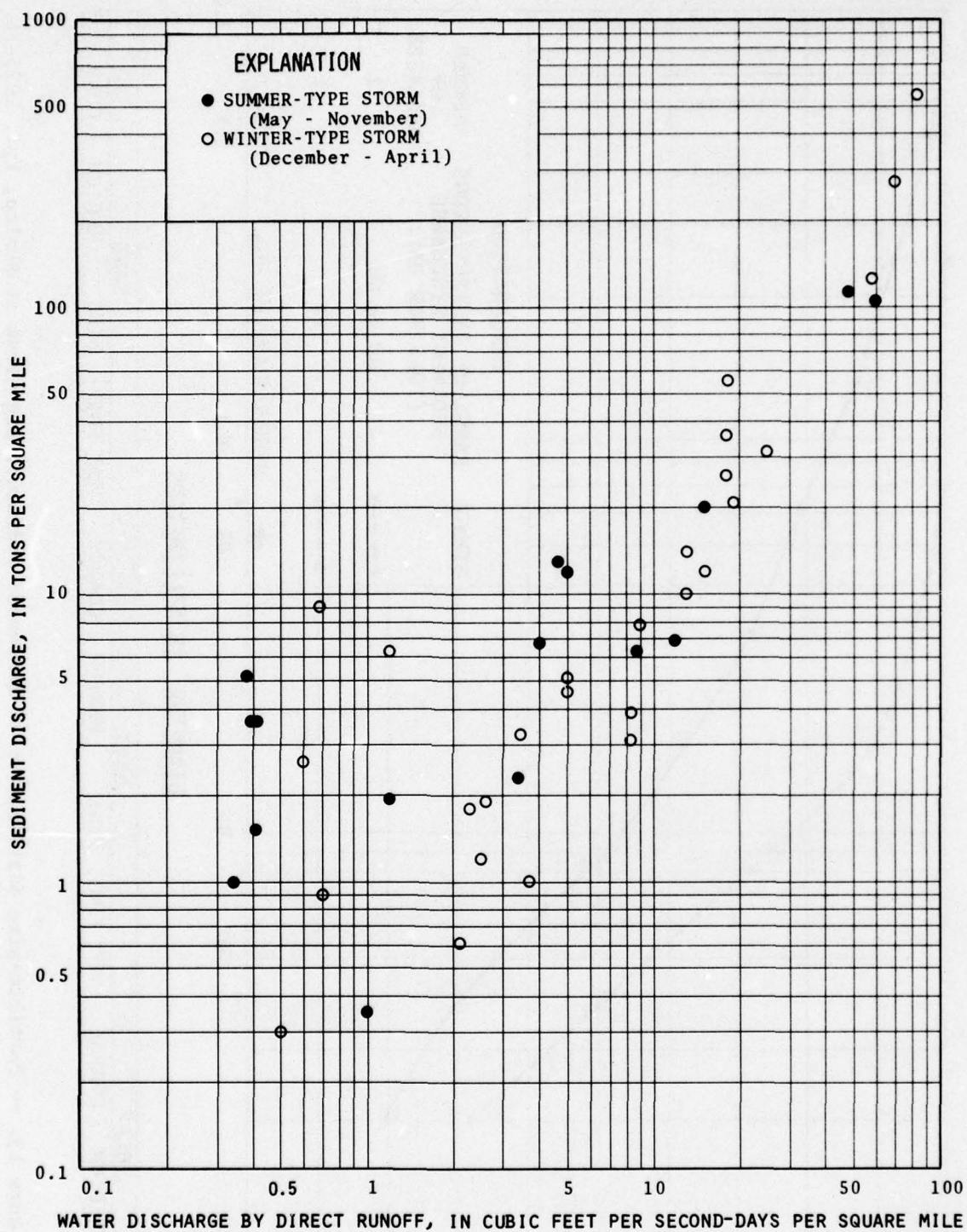


Figure 12. -- Relation of sediment discharge to water discharge by storms, Feds Creek at Feds Creek, Ky., 1973-75.

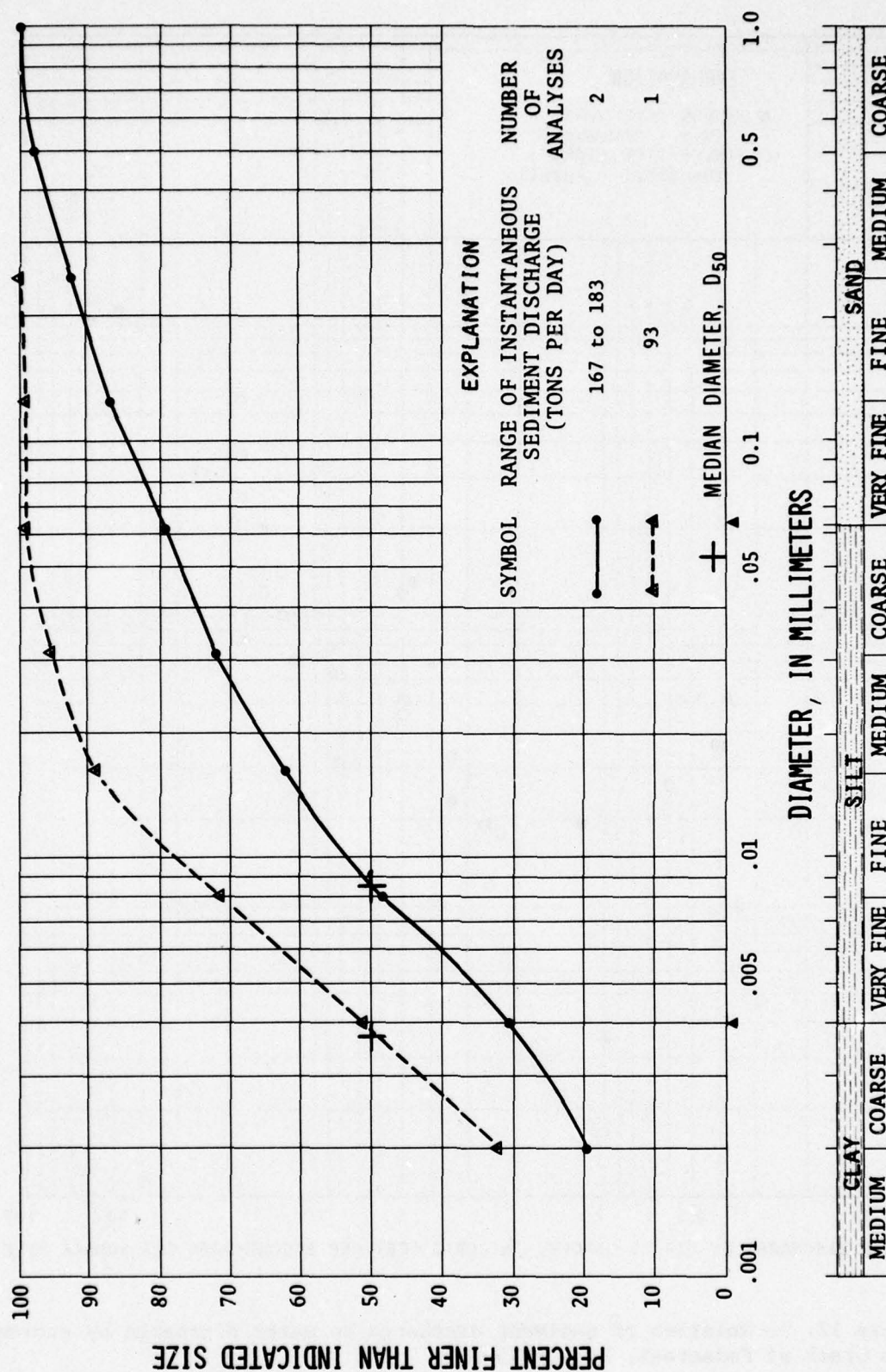


Figure 13. -- Particle-size distribution of suspended sediment, Big Creek at Dunlap, Ky., 1975-76.

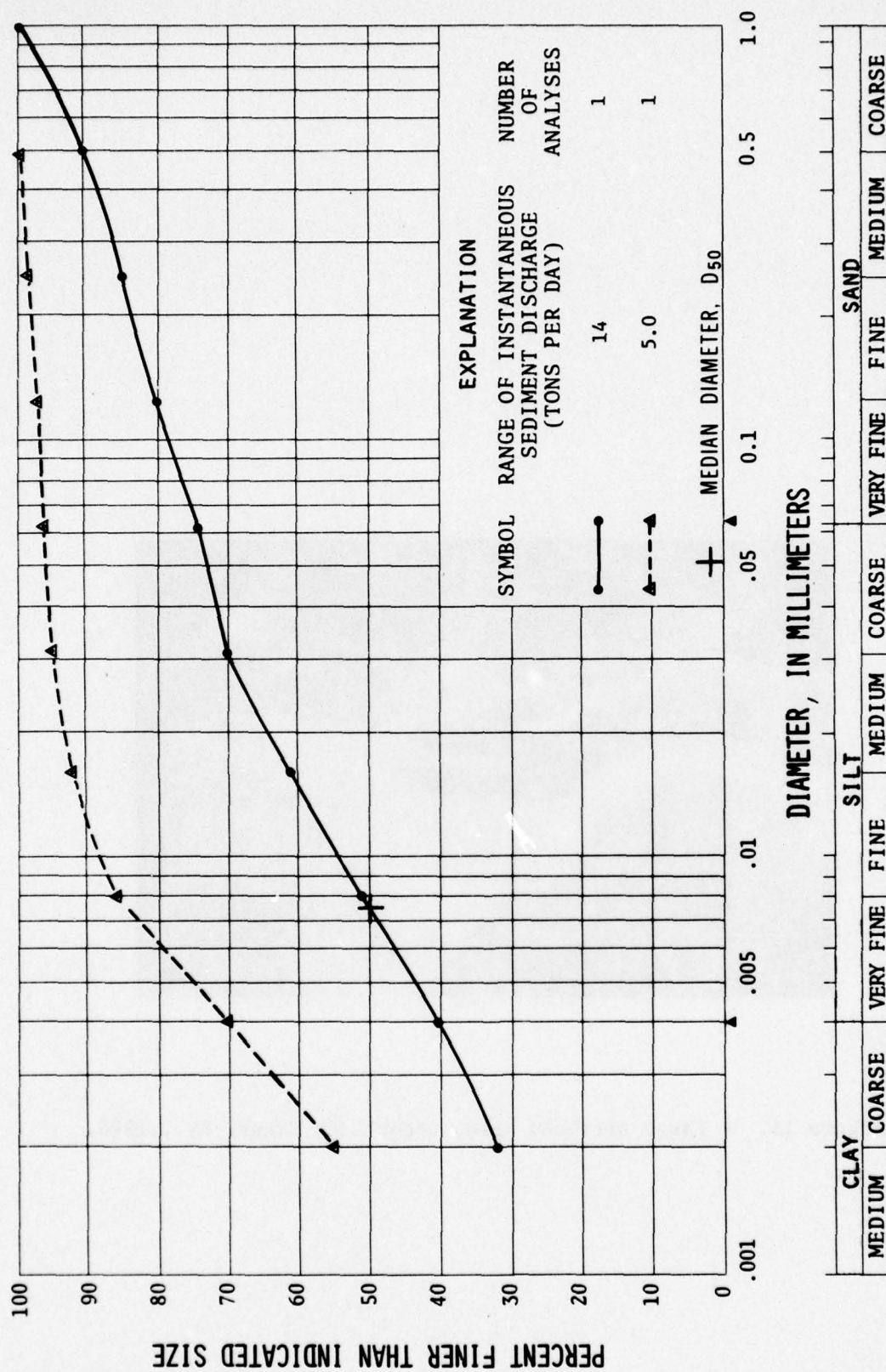


Figure 14. -- Particle-size distribution of suspended sediment, Island Creek near Phyllis, Ky., 1975.



Figure 15. -- Large stripped area, upper Lick Creek, Ky., 1976.

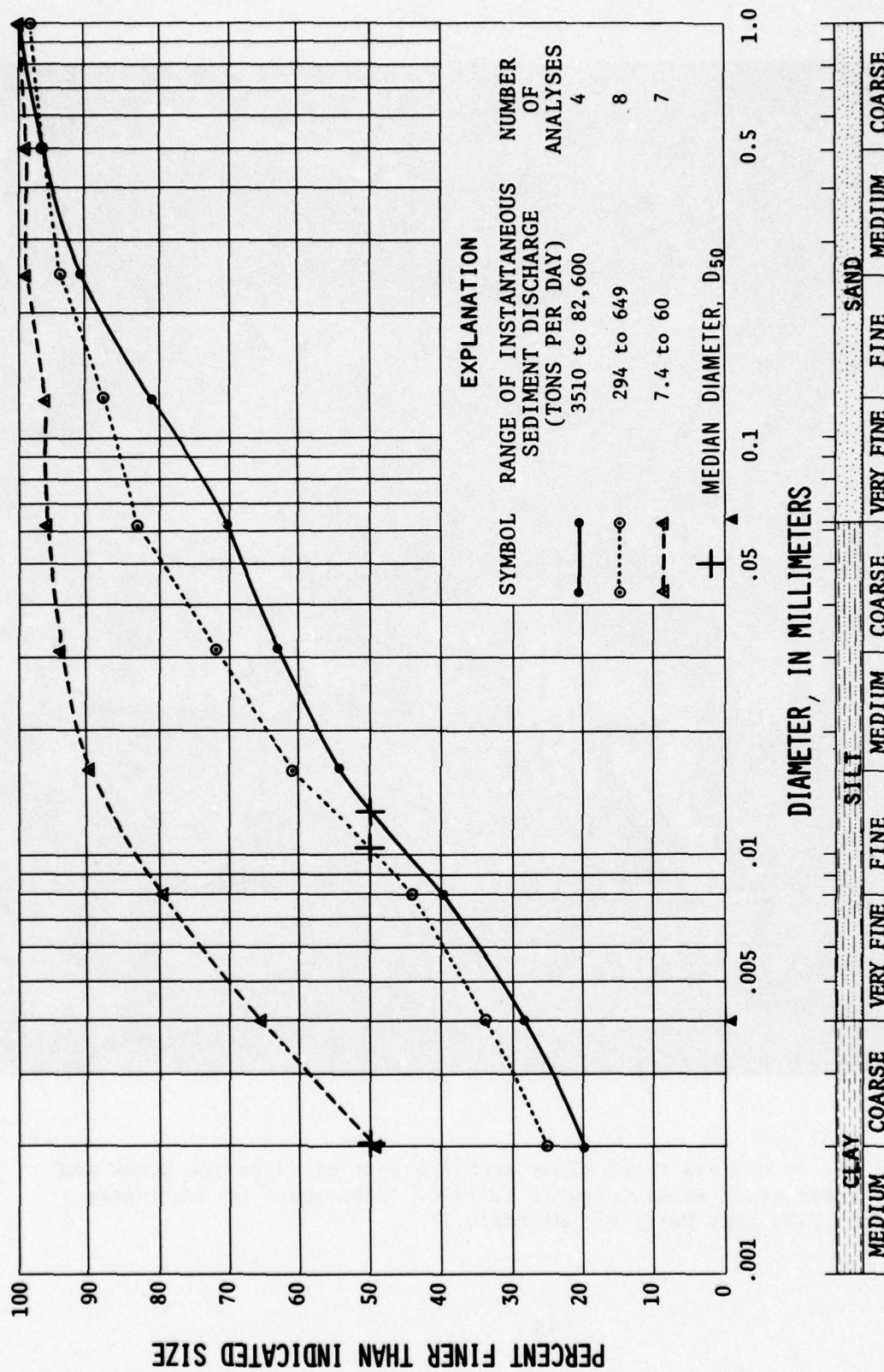


Figure 16 -- Particle-size distribution of suspended sediment, Millers Creek near Phyllis, Ky., 1973-76



Figure 17. -- Millers Creek study area and part of Grapevine Creek and Island Creek study areas, October 5, 1974. (Photograph by Huntington District, U.S. Army Corps of Engineers.)

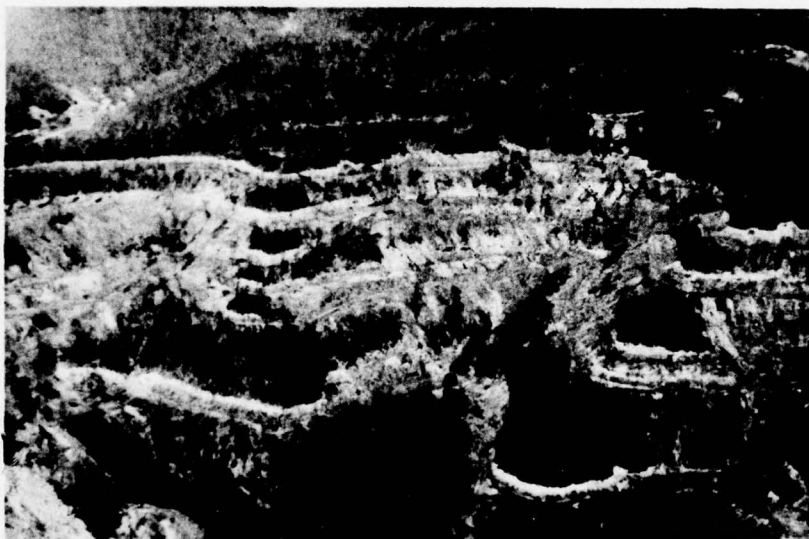


Figure 18. -- Upper Millers Creek showing effects of auger-strip mining, 1976.

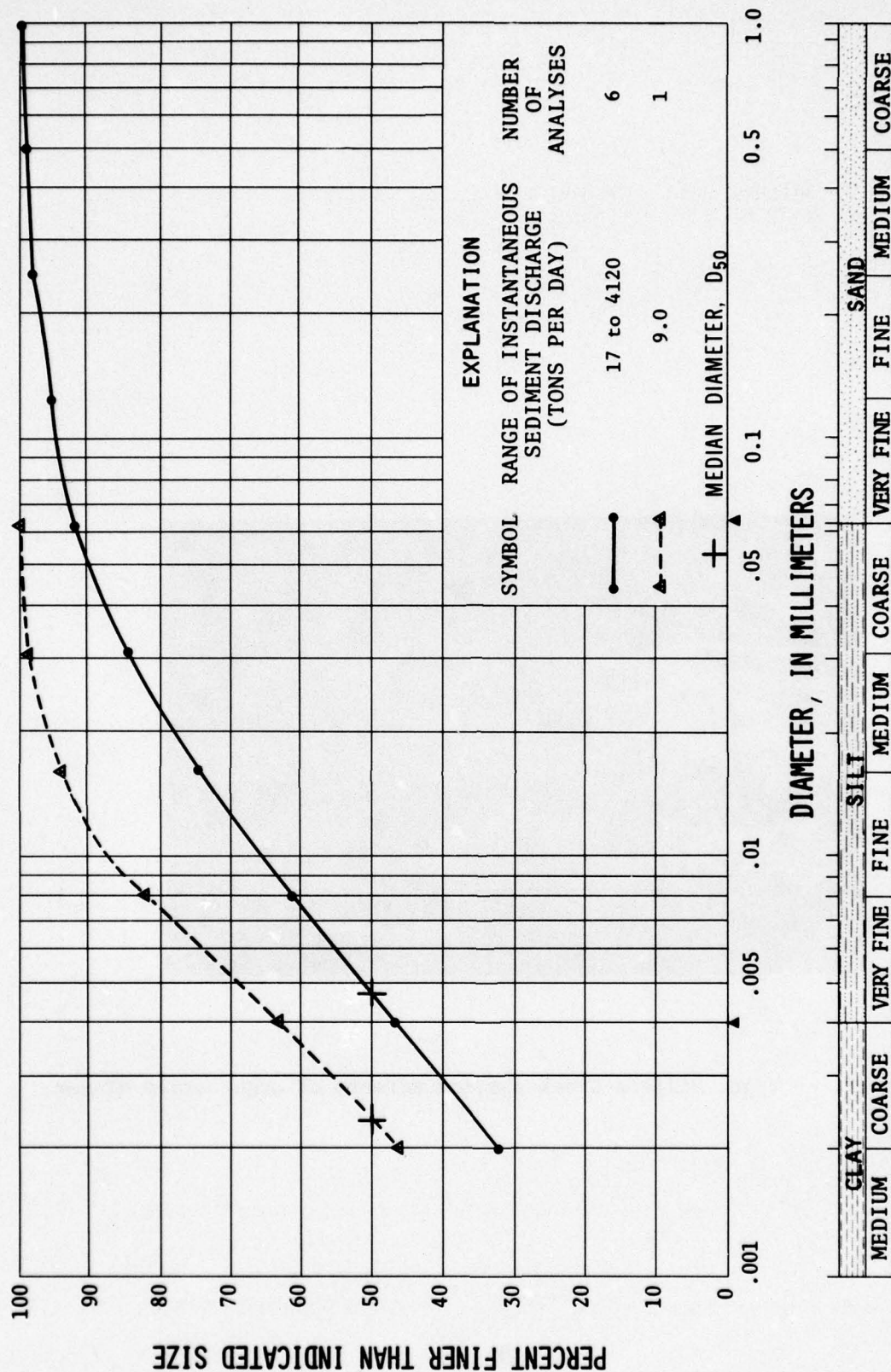


Figure 19. -- Particle-size distribution of suspended sediment, Millers Creek near Phyllis, Ky., 1973-74.

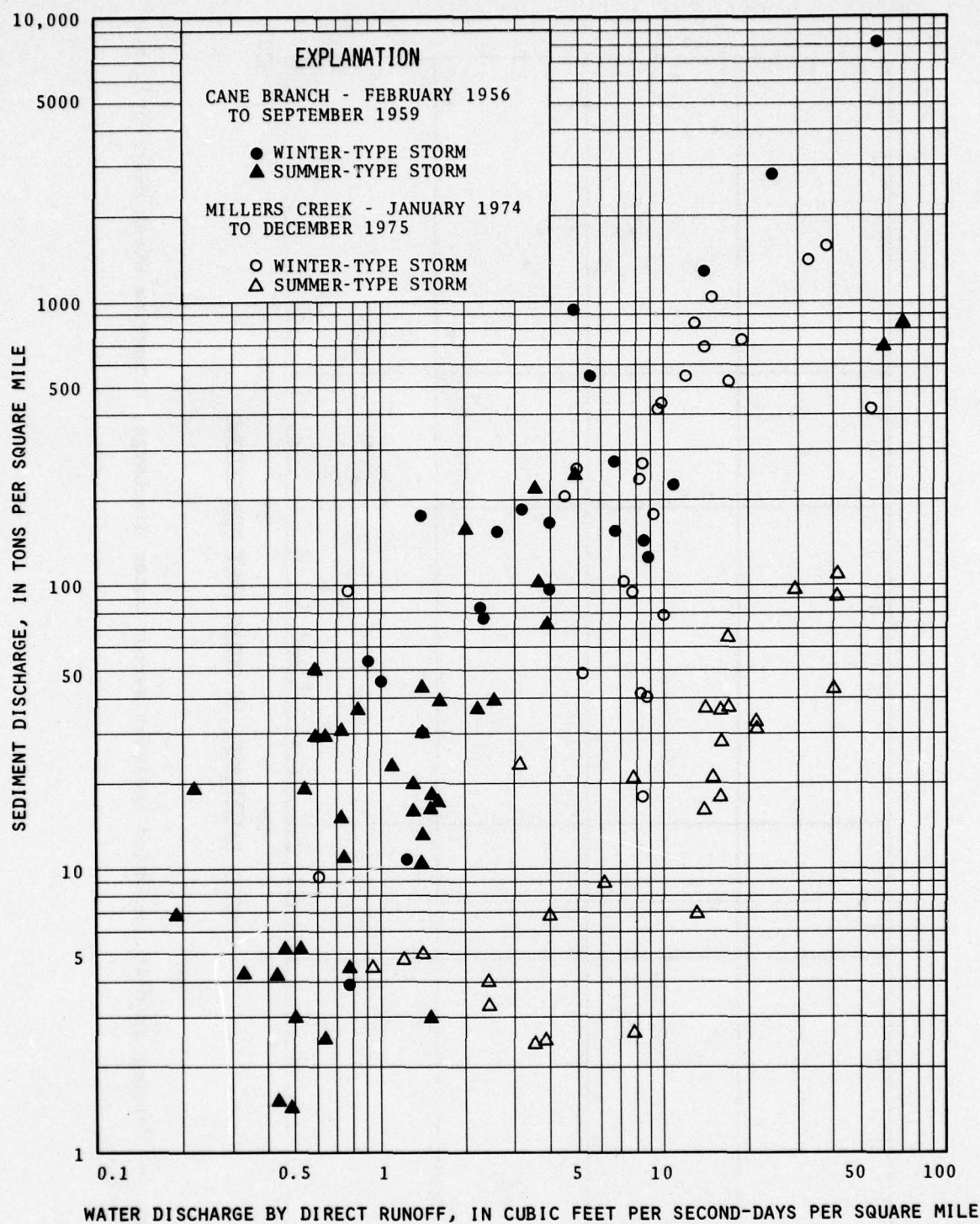


Figure 20. -- Relation of sediment discharge to water discharge by storms, for Cane Branch near Parkers Lake, Ky., and Millers Creek near Phyllis, Ky.

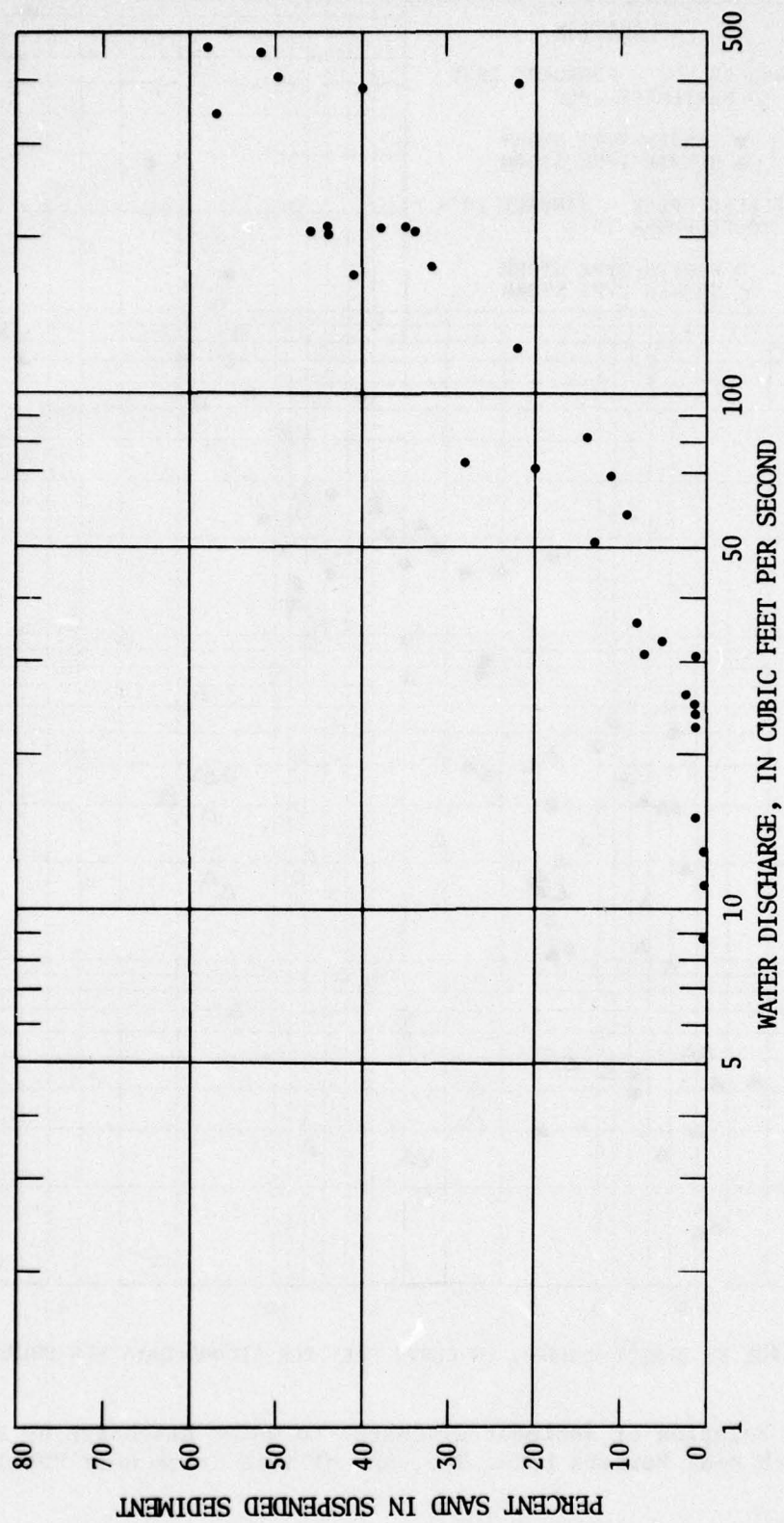


Figure 21. -- Percent sand in suspended sediment versus water discharge, Grapevine Creek near Phyllis, Ky., 1974-75.

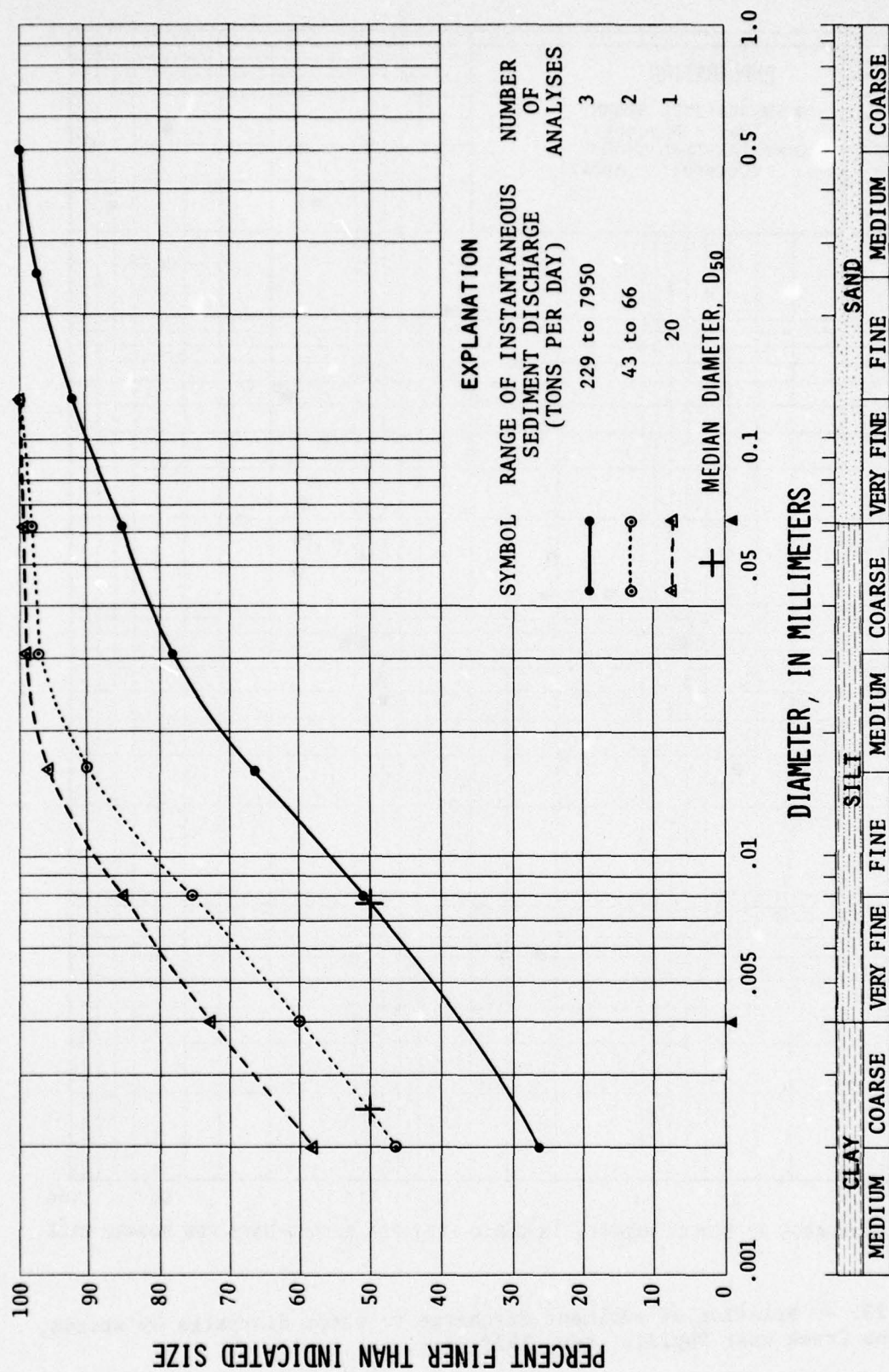


Figure 22. -- Particle-size distribution of suspended sediment, Grapevine Creek near Phyllis, Ky., 1973-76.

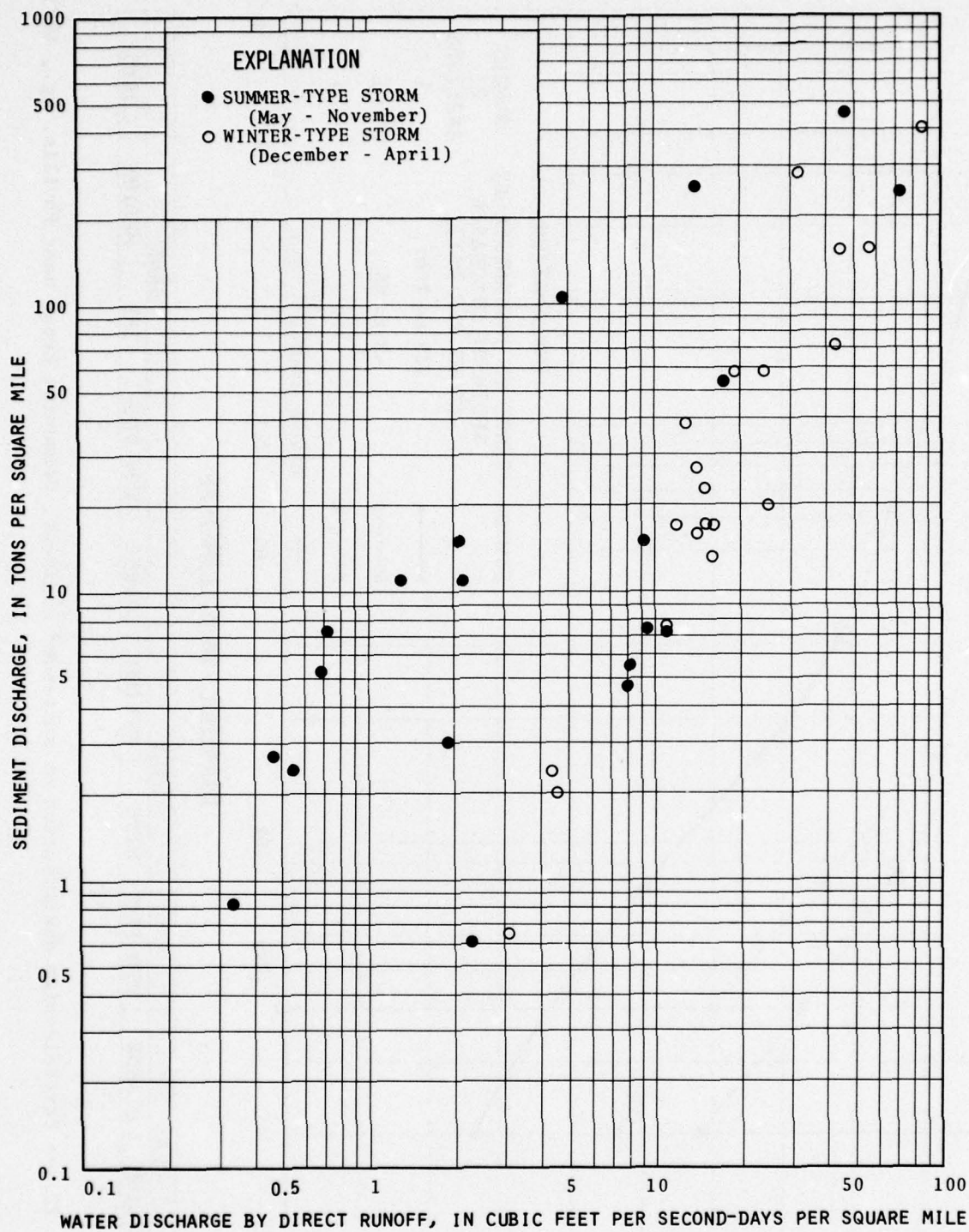


Figure 23. -- Relation of sediment discharge to water discharge by storms, Grapevine Creek near Phyllis, Ky., 1973-75.

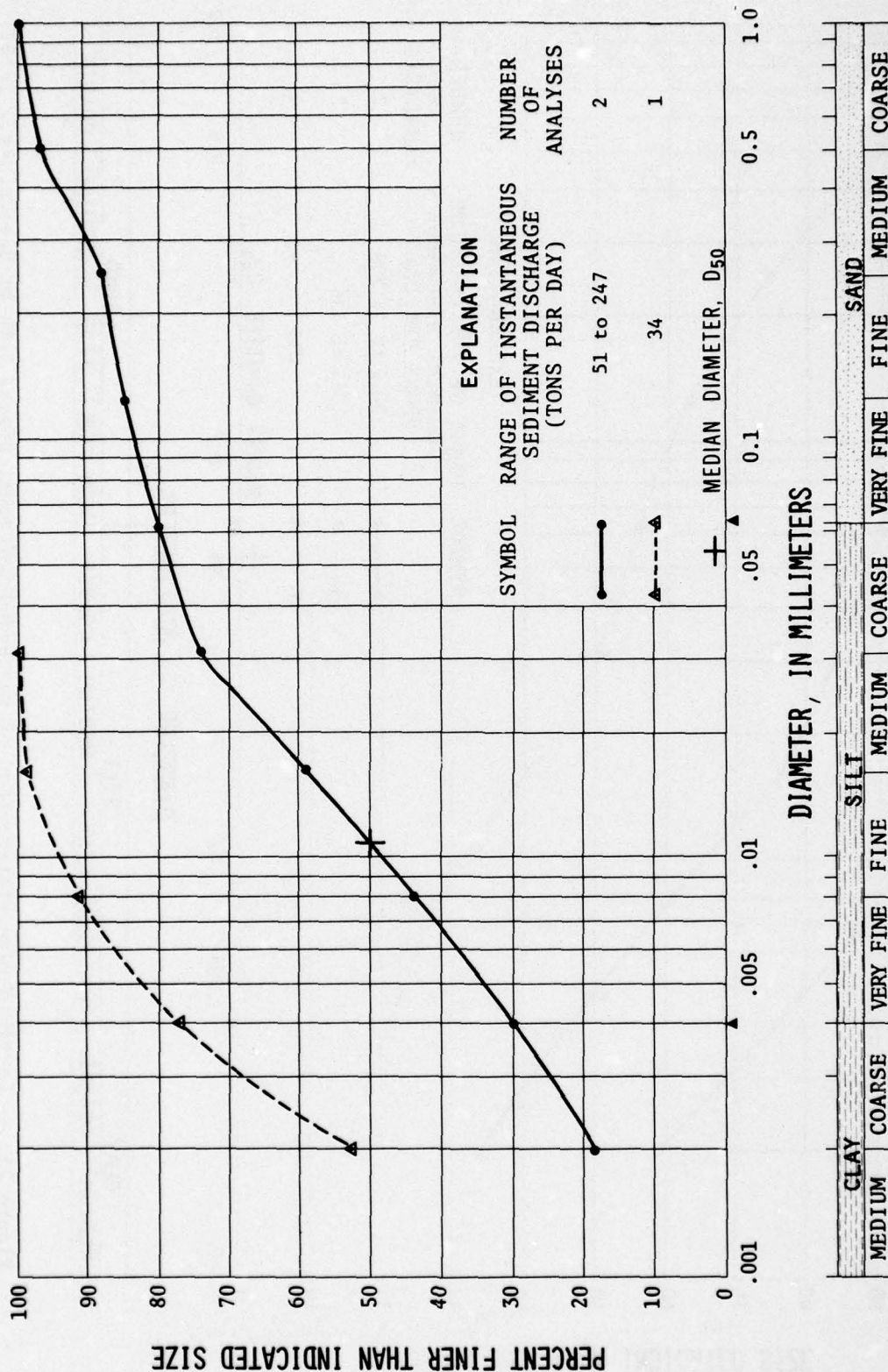


Figure 24. -- Particle-size distribution of suspended sediment, Johns Creek near Meta, Ky., 1976.

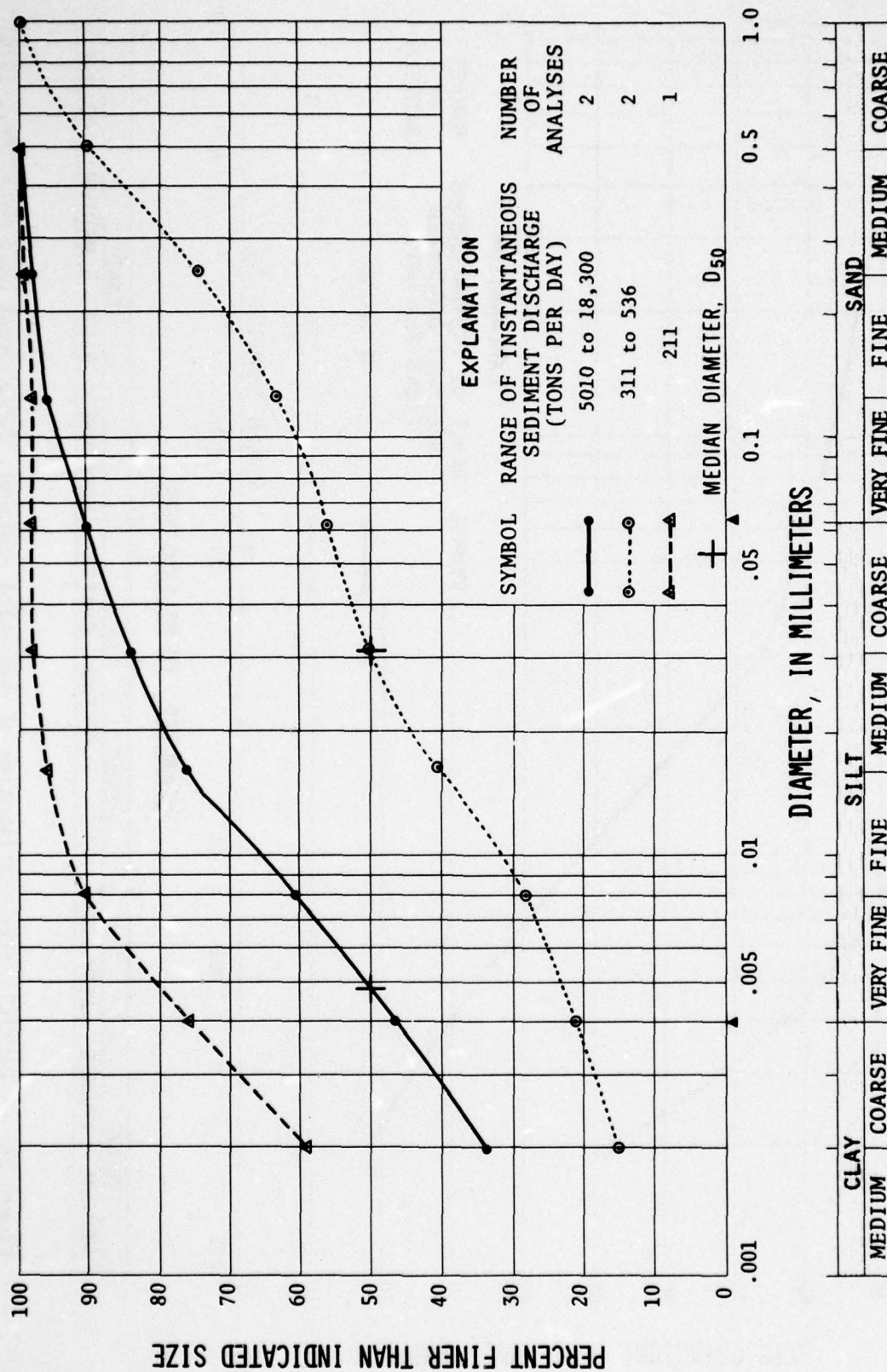


Figure 25. -- Particle-size distribution of suspended sediment, Brushy Fork at Heenon, Ky., 1976.

TRANSFER VALUE OF RESULTS

The transfer of sediment-yield results from measured basins to unmeasured basins is not an exact science. When attempting to transfer data, factors that affect sediment yield in one basin should be comparable to those of the other basin. An evaluation of the following factors should be made for both basins: Relative location of the two basins; extent of vegetative cover; frequency, intensity, form, and amount of precipitation; runoff; soil texture; slopes of channels and valley sides; extent of channelization; extent of disturbance by man of the natural basin features; and the type of land uses in the basin.

Naturally, the more similar these factors are for the two basins, the more dependable the transfer of data between basins. For example, transferring data between two basins located in the same general area, and undergoing surface mining, should give better results than the transfer of data between an unmined area and a mined area. An example of the possibilities of transferring data between two strip-mined areas could be the relation of data from Cane Branch and Millers Creek shown in fig. 20. Millers Creek data, while not coinciding precisely with Cane Branch data, does plot in the same general area, and at the same general magnitudes. The sediment-discharge characteristics of the two basins can be considered to have some similarities.

Data collected during the study at Grapevine Creek at Phyllis, Ky. (an unmined area) were used to satisfactorily estimate the sediment yields in unmined and unmeasured areas of the Levisa and Johns Creek basins. This was practical because many of the sediment-yield-affecting factors could be and were held constant. Because they were insignificant in Grapevine Creek, they were considered insignificant in the estimated areas as yields in only 12 percent of Levisa Fork were undefined.

The data relating to the sediment-yield-affecting factors between measured and unmeasured mine basins were insufficient to make realistic transfers of data. This was due to the extremely complex changes which were taking place in basins undergoing surface mining and which affected the sediment-yield-affecting factors in different ways.

In the case of Johns Creek basin, no base value existed to accurately estimate the 51 percent of unknown areal sediment yield. Grapevine Creek's sediment yield data gave too high a figure. It was determined that some of the underground-mined basins of Levisa Fork gave a better estimate for unmined unmeasured areas in Johns Creek basin than Grapevine data. The average sediment yields of unmeasured areas in Johns Creek basin were best estimated from sediment outflow data from reservoir deposition data, and from known areal yields.

RESERVOIR TRAP EFFICIENCY

Fishtrap Reservoir

The trap efficiency of Fishtrap Reservoir was computed for the 2-year data-comparison period of January 1974 to December 1975. Reservoir sediment surveys by the U.S. Army Corps of Engineers had been made in January 1974 and in September 1975, and revealed an average annual deposition rate of 464 acre-ft of sediment (U.S. Army Corps of Engineers, 1976a, Exhibit No. 43). Using an average dry weight per cubic foot of 60.5 lbs., the annual weight of deposited sediment was 611,000 tons. This rate was used for the 2-year data-comparison period and resulted in a total deposition of 1,223,000 tons.

Intermittent samples had been collected during the period at the outflow station, Levisa Fork below Fishtrap Dam near Millard, Ky. The samples formed the basis for the development of two sediment-transport curves which were used to compute the sediment discharge from Fishtrap Reservoir. One curve represented the period November and December each year when the lake was drawn down to winter pool. The other curve was for the remaining 10 months of each year. The outflow sediment discharge which was determined for this station was 147,000 tons for the 2-year period. Combining this figure with the weight of deposited sediment provided the total sediment inflow figure of 1,370,000 tons. The trap efficiency of Fishtrap Reservoir, by the definition given in the glossary of terms, was the percentage of the sediment inflow which was deposited in the reservoir, or

$$\text{T.E.} = \frac{1,223,000}{1,370,000} \times 100 = 89 \text{ percent}$$

Dewey Reservoir

The trap efficiency of Dewey Reservoir was computed for the 1-year data-comparison period, January to December 1975. Reservoir sediment surveys had been made by the U.S. Army Corps of Engineers in November 1973 and in November 1975, and revealed an average annual deposition rate of 146.5 acre-ft, (U.S. Army Corps of Engineers, 1976b, Exhibit No. 52). Using an average dry weight per cubic foot of 55 lbs., the average annual weight of deposited sediment was 175,000 tons. This rate was used for the data-comparison period.

An excellent record of sediment discharge from Dewey Reservoir had been collected from November 11, 1974 to December 31, 1975. The suspended-sediment discharge during the 1975 calendar year (data-comparison period) was 106,000 tons. Adding this figure to the deposited tonnage results in a total sediment inflow of 281,000 tons. Trap efficiency of Dewey Reservoir was computed as follows:

$$\text{T.E.} = \frac{175,000}{281,000} \times 100 = 62 \text{ percent}$$

CHEMICAL QUALITY

By

John F. Santos

When the land surface is disturbed, especially on a large scale such as from strip mining, minerals that are soluble or readily oxidized are often exposed. The weathering and solution or oxidation of these minerals is often evident in an increase in mineral content and a change in the physical properties of the water in streams draining the disturbed area.

Underground mining will also expose minerals to weathering or oxidation and also provides a conduit for the drainage of ground water which may act as a solvent for minerals oxidized upon exposure in the mine workings.

Pyrite and marcasite and other forms of iron-sulfide minerals are often associated with coal or other rocks in the coal measures (Moulton, E. Q. and others, 1957, p. 5). Some of these minerals weather rapidly upon exposure, oxidizing to iron sulfate, and if water is present, forming sulfuric acid in addition. These products upon entering a stream can greatly alter the chemical composition and physical properties of the water. Added to a stream containing alkaline water, the iron is precipitated (yellow boy), and the acid often neutralized; but the sulfate remains in solution. Added to a stream containing acid water, it is likely that less iron will precipitate and the acidity will increase. In both cases, sulfate will remain in solution; thus, the concentration of dissolved sulfate is important in assessing the origin and chemical quality of streams that drain basins where coal has or is being mined.

Water from the streams at the water quality sampling sites (figs. 26 and 27) was generally alkaline in both the Levisa Fork and Johns Creek basins. Some pH values were less than 7.0; however, all waters sampled contained some bicarbonate, and none of them contained a sufficient concentration of hydrogen ion to indicate acid water is reaching the streams sampled. This does not preclude the possibility of acid water in the streams above the sampling points. But if acid water is present in the upper parts of the basins it is neutralized by the time it reaches the lower part of the basins.

The Stiff diagrams (Stiff, 1951, p. 15) shown in figs. 26 and 27 give a visual characterization of the water in the streams at selected high and low flows. The diagrams show the ionic strength of the principal anions and cations in the water.

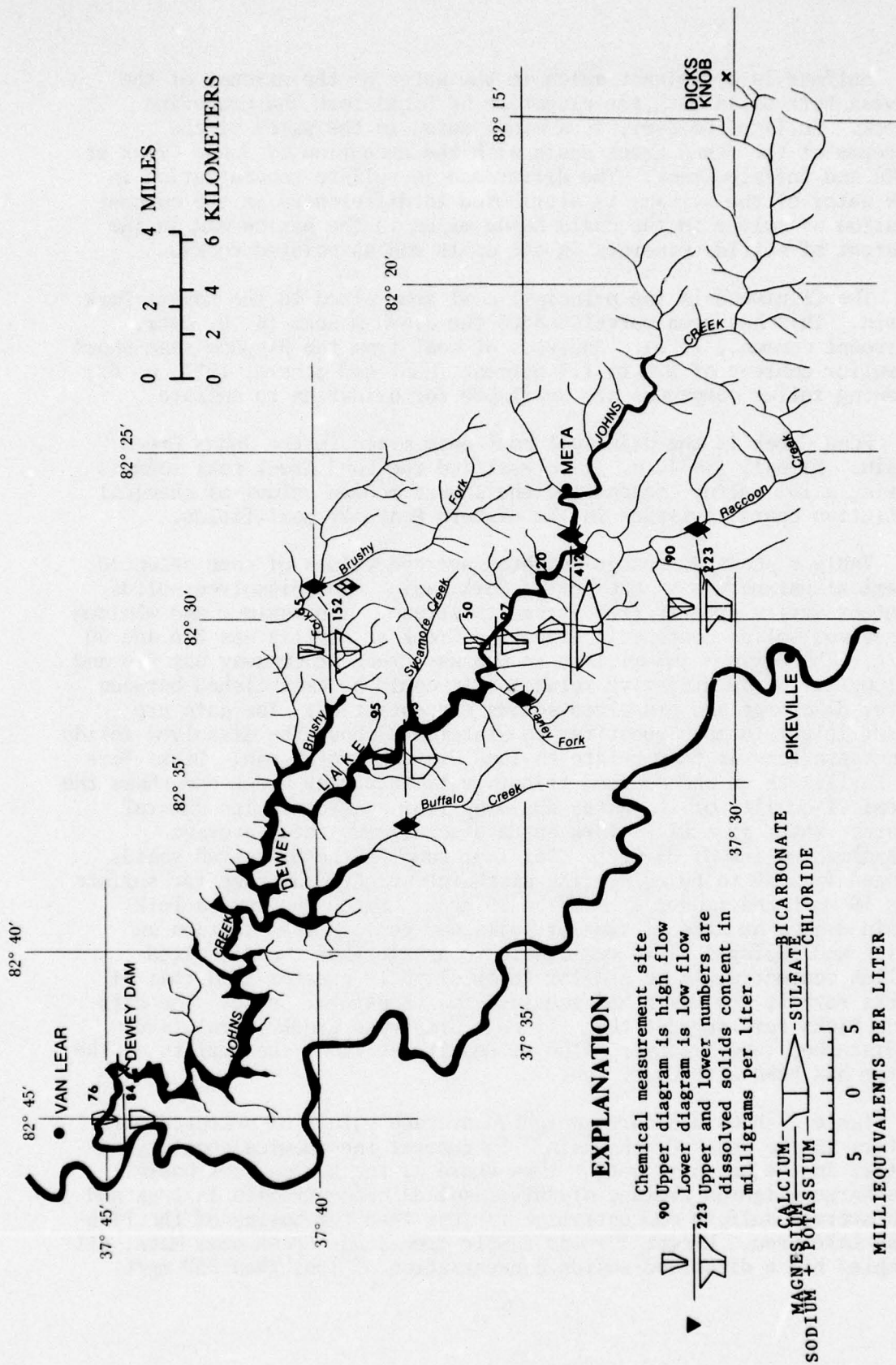


Figure 27. -- Stiff diagrams of selected high and low flows; Johns Creek drainage basin in the vicinity of Dewey Lake.

Sulfate is a dominant anion in the water of the streams of the Levisa Fork basin with the exception of Dicks Fork and Grapevine Creek. Sulfate, however, is a minor anion in the water of the streams of the Johns Creek basin with the exception of Johns Creek at Meta and Buffalo Creek. The difference in sulfate concentration in the water of the streams is attributed to differences in the concentration of sulfur in the coals being mined in the basins and in the content of sulfide minerals in the coals and associated rocks.

The Clintwood is the principal coal seam mined in the Levisa Fork basin. This has been correlated to the Bingham seam (K. L. Dyer, personal commun., 1976). Analyses of coal from the Bingham seam shows a sulfur content of 0.9 to 1.7 percent (Hunt and others, 1937, p. 62) showing sulfur compounds are available for oxidation to sulfate.

Pond Creek is the principal coal seam mined in the Johns Creek basin. Kimball (1974, p. 31) classified the Pond Creek coal seam as having a low sulfur content and the lowest median values of chemical pollution characteristics in the eastern Kentucky coal fields.

Table 6 shows discharge-weighted average values of some selected chemical parameters in the Levisa Fork basin. The dissolved-solids content varies greatly from stream to stream. The maximum and minimum dissolved-solids content in Grapevine Creek at Phyllis was 216 and 60 mg/L. The maximum and minimum in Conaway Creek at Conaway was 916 and 701 mg/L. No quantitative relationship could be established between water discharge and dissolved-solids concentration. The data are insufficient to make quantitative statements about the dissolved-solids concentrations as they relate to land disturbance by man. Dicks Fork at Phyllis is an undisturbed tributary to Grapevine Creek and shows the chemical quality of the water draining from an area in its natural state. Water from Dicks Fork has a discharge-weighted average dissolved solids of 54 mg/L. For four samples the dissolved solids ranged from 50 to 60 mg/L. The discharge-weighted average for sulfate was 19 mg/L and ranged from 17 to 19 mg/L. Since the Levisa Fork basin drains an area of similar soils and geology (see section on soils and geology) it is reasonable to assume that the dissolved-solids content would be similar to or slightly greater than that of Dicks Fork if the basin had remained in its natural state. The data from Dicks Fork suggest that although Grapevine Creek is relatively undisturbed (see Transfer Value of Results section) the quality of the water has been altered by man.

Table 7 shows discharge-weighted average values of selected parameters in the Johns Creek basin. In general the chemical quality of waters in the basin is better than those of the Levisa Fork basin. Discharge-weighted average dissolved-solids concentration is less and the average sulfate concentration is less than the basins of the Fish-trap Lake area. Except for one sample from Johns Creek near Meta, all samples had a dissolved-solids concentration of less than 250 mg/L.

Table 6.--Values for selected chemical parameters in waters of the Levisa Fork basin

	Average water dis- charge ft ³ /s	Discharge weighted average dissolved solids in mg/L	Discharge weighted average sulfate, in mg/L	1975 coal produc- tion in tons
Dicks Fork at Phyllis, Ky.....	0.79	54	19	0
Grapevine Creek near Phyllis, Ky..	11.5	163	25	10,938
Island Creek near Phyllis, Ky.....	1.3	212	99	249,256
Big Creek at Dunlap, Ky.....	7.4	314	177	814,826
Lick Creek at Lick Creek, Ky.....	5.1	370	204	317,300
Feds Creek at Fedscreek, Ky.....	5.8	389	224	71,714
Millers Creek near Phyllis, Ky....	1.1	470	266	269,236
Card Creek at Mouthcard, Ky.....	2.6	441	268	192,569
Conaway Creek at Conaway, Va.....	8.2	730	403	unknown
Levisa Fork at Big Rock, Va.....	168	306	156	unknown
Levisa Fork below Fishtrap Dam, Ky.	274	255	136	--

Table 7.--Values for selected chemical parameters
in waters of the Johns Creek basin

	Average water dis- charge ft ³ /s	Discharge weighted average dissolved solids in mg/L	Discharge weighted average sulfate, in mg/L	1975 coal produc- tion in tons
Caney Fork near Gulnare, Ky....	3.1	53	17	541,846
Brushy Fork at Heenon, Ky.....	19	84	27	719,364
Raccoon Creek near Zebulon, Ky.	8.9	92	29	602,777
Buffalo Creek near Endicott, Ky.	7.5	94	39	180,616
Johns Creek near Meta, Ky.....	62	134	62	2,227,215
Johns Creek near Van Lear, Ky...	333	82	30	--

The much larger sulfate values compared with those in Dicks Fork at Phyllis lend support to the belief that man's activities in the basin have increased the dissolved-solids content and sulfate concentration of water in these streams.

Figure 28 is a graph of 1975 coal production versus discharge-weighted average sulfate concentration for streams in the Levisa Fork and Johns Creek basins. The graph is not a straight mathematical relation, but the trend is evident that increased coal production in the Levisa Fork is accompanied by increased sulfate concentrations. Although large quantities of coal are mined in the Johns Creek basin, the effect on water quality is less than that in the Levisa Fork basin. The increase in sulfate concentration in Johns Creek basin appears to be related to the percentage of disturbed land and surface mining-operations (table 1, fig. 6).

At low flow, (figs. 26 and 27), streamflow is comprised predominately of ground-water discharge and drainage water from both underground and surface mines. Water from most of the streams in the Levisa Fork basin is a calcium-magnesium sulfate type although several basins such as Big Creek and Island Creek have water that is also high in bicarbonate. Water from streams in the Johns Creek basin is principally a calcium-magnesium bicarbonate type. The bicarbonate in the water of both basins probably is derived from limestone or carbonate nodules and disseminated carbonate in the rocks associated with coal.

Water from Grapevine Creek is dissimilar from water of other basins. The low sulfate concentration may be indicative of the small amount of coal mined in the basin or that the coal mined has a low sulfur content. Sodium and chloride in the water could be either from mine drainage or possibly from sewage effluent. The concentration of ions in the water is such that a stockpile of highway road salt could be a source of some of the ions. Lack of dilution of the ions at high flows would indicate that the source is abundant and readily available to go into solution.

Water in the streams at high flow is predominantly precipitation running off the land surface. The chemical composition of the water reflects readily soluble minerals at or near the land surface that are incorporated in the runoff and the dilution of the more mineralized water from mine drainage and ground-water discharge.

The percentage of the individual ions in relation to each other remains about the same at high flow as at low flow, but there are some exceptions. Sulfate usually shows a percentage increase at the expense of bicarbonate. The implication is that additional sulfate is being contributed to the streams in runoff during major rainstorms. The source, therefore, is from the land surface, possibly from areas where the land surface has been disturbed by strip mines, haul roads, or construction activity.

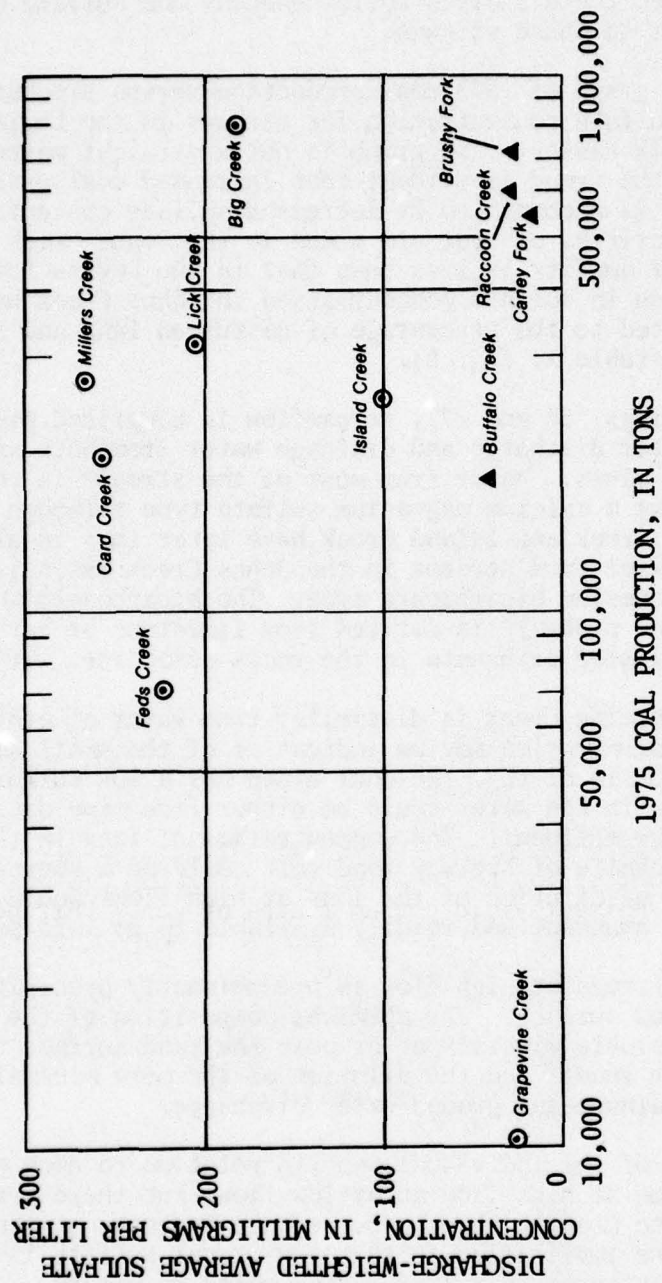


Figure 28. -- Coal production versus discharge-weighted average sulfate concentration for streams in Levisa Fork and Johns Creek basins, Kentucky.

Streams, whose water shows the greatest dilution of mineral content during high flow, are those in which underground mining is predominant. The significant reduction in sodium, potassium, and bicarbonate in the water of Big Creek, Island Creek, and Raccoon Creek for example, indicate that drainage from underground mines in these basins is likely the source of these ions.

Very little difference in concentration of the major ions is evident between the high and low flow discharge from the respective lakes (figs. 26 and 27). This is to be expected as the lakes act as mixing bodies for all the inflow to them. The chemical quality of the outflow from the lakes appears to be somewhat better than that of the inflow based on the Stiff diagrams (figs. 26 and 27). This apparent discrepancy is due to the contribution of water of low mineral content from rainfall on the lakes and inflow from ungaged and undisturbed areas in the basin such as Dicks Creek.

SUMMARY

Sediment yields ranged from 2,890 to 21,000 tons/mi² for study areas where surface-mining techniques predominated, and ranged from 732 to 3,470 tons/mi² where underground-mining methods prevailed.

Water and sediment discharges from direct runoff during storms on Millers Creek when plotted with Cane Branch of Beaver Creek in McCreary County, Ky., grouped similarly by season and magnitude. A possible method of comparing results was indicated, but was not accurate enough to adopt as a transfer method.

A high percentage-disturbed area usually indicated a correspondingly high sediment yield, but a direct relationship did not always hold. However, sediment yield per unit area at Caney Fork near Gulnare, Ky., was about 100 times greater in October-November 1975, after surface mining started than for the same 2-month period a year earlier, before mining had begun. This large increase occurred, even though water discharge was only four times greater in 1975 than the same period in 1974.

An evaluation of storm-rainfall intensity using rainfall data from Lick Creek revealed that the highest intensities occurred in April, May, and June.

Summer storms produced more sediment per unit of runoff than winter storms in surface-mined basins.

Between October 1974 and April 1975, disturbed acreage due to mining in Johns Creek basin and Levisa Fork basin (excluding the area in Virginia) increased by 926 acres.

The overall average sediment yields for Fishtrap and Dewey Lakes' drainage areas were 1,770 and 1,400 tons/mi², respectively.

The annual deposition rate of sediment into Fishtrap Lake was 464 acre-ft and for Dewey Lake was 146 acre-ft. Trap efficiency of Fishtrap Lake is 89 percent, and for Dewey Lake is 62 percent.

Sixty-three percent of the sediment inflow to Fishtrap Lake during 1974 and 1975 was measured at two stations in Virginia. The balance had its origin in the areas immediately surrounding the lake.

Based on the 34-year flow record at Johns Creek at Meta, average discharges for 1974 and 1975 were 69 percent and 55 percent above normal, respectively. Since rainfall was also much higher than normal, one may expect that sediment yields during the study period were higher than normal provided all other erosion-causing factors remained unchanged.

Very low percentages of coal (usually five or less) were present in those samples selected for percent coal analysis.

Particle-size analyses of suspended sediment indicated in most instances that the higher the sediment discharge the larger the median diameter of the sample, or the coarser the sample.

Higher dissolved solids and turbidity in flowing water is related to an increase of man's activities in the watershed. No quantitative measure of water-quality impairment can be made for streams in the Levisa Fork basin above Fishtrap Dam. However, comparing water-quality data from these streams with data from an undisturbed stream suggests that sulfate and dissolved-solid concentrations are generally higher in streams draining disturbed basins. Man's activities in the Johns Creek basin have had a much smaller influence on the water quality when compared to the Levisa Fork basin above Fishtrap Dam.

The data suggest that the Bingham coal seam contains sulfur compounds that cause increased sulfate concentrations in the streams draining the mined areas. Conversely, although large quantities of coal are mined in the Johns Creek basin, the principal coal seam (Pond Creek) being mined in the basin has a small effect on the chemical quality of the water.

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SUPPLEMENTARY DATA

Table 8.--Locations of sampling stations in Levisa Fork
and Johns Creek drainage basins

<u>USGS station number</u>	<u>Station name</u>	<u>Location</u>	<u>Basin on 7.5 minute topographic maps</u>
03207800	Levisa Fork at Big Rock, Va.	Lat 37°21'13", long 82°11'45", Buchanan County, on left bank at Big Rock, 0.4 mi downstream from Rocklick Creek, and 0.5 mi down- stream from bridge on State Highway 645.	Amonate Big A Mountain Bradshaw Elkhorn City Grundy Harman Honaker Hurley Jamboree Jewell Ridge New Keen Mountain Patterson Prater Vansant
03207805	Conaway Creek at Conaway, Va.	Lat 37°20'45", long 82°12'29", Buchanan County, on right bank at bridge on State Highway 610, and 0.4 mi south of Conaway, and at mile 0.4.	Elkhorn City Harman
03207345	Card Creek at Mouthcard, Ky.	Lat 37°22'54", long 82°15'30", Pike County, on left bank on Card Creek Road, 0.2 mi downstream from Road Fork, 0.2 mi west of Mouthcard, and at mi 0.2.	Elkhorn City Lick Creek
03207875	Feds Creek at Feds creek, Ky.	Lat 37°24'07", long 82°14'38", Pike County, on right bank adjacent to State Highway 366, at Feds creek, 0.2 mi downstream from Dry Fork, and at mile 0.3.	Jamboree

Table 8.--Locations of sampling stations in Levisa Fork
and Johns Creek drainage basins--continued

<u>USGS station number</u>	<u>Station name</u>	<u>Location</u>	<u>Basin on 7.5 minute topographic maps</u>
03207905	Big Creek at Dunlap, Ky.	Lat 37°25'43", long 82°14'52", Pike County, on right bank adjacent to State Highway 194, 0.2 mi downstream from Linn Branch, and at mile 1.0.	Jamboree
03207925	Island Creek near Phyllis, Ky.	Lat 37°25'23", long 82°18'17", Pike County, on left bank, adjacent to Island Creek Road, 0.5 mi downstream from Left Fork, 2.2 mi southeast of Phyllis, and at mile 0.3.	Lick Creek
03207935	Lick Creek at Lick Creek, Ky.	Lat 37°23'44", long 82°18'08", Pike County, on right bank, adjacent to Lick Creek road, 0.2 mi downstream from School- house Branch, 0.3 mi upstream from Miletree Branch, and at mile 1.4.	Elkhorn City Lick Creek
03207940	Millers Creek near Phyllis, Ky.	Lat 37°25'19", long 82°19'53", Pike County, on left bank, adjacent to Millers Creek Road, 0.2 mi downstream from Second Fork, 0.3 mi upstream from First Fork, 1.5 mi south of Phyllis, and at mile 0.6.	Lick Creek
03207965	Grapevine Creek near Phyllis, Ky.	Lat 37°25'57", long 82°21'14", Pike County, on right bank, at Grapevine Recreation area, 1.3 mi downstream from Dicks Fork, 1.3 mi southwest of Phyllis, and at mile 1.1.	Lick Creek

Table 8.--Locations of sampling stations in Levisa Fork
and Johns Creek drainage basins--continued

<u>USGS station number</u>	<u>Station name</u>	<u>Location</u>	<u>Basin on 7.5 minute topographic maps</u>
03207962	Dicks Fork at Phyllis, Ky.	Lat 37°26'57", long 82°20'16", Pike County, on right bank along Dicks Fork, 0.5 mi (0.8 km) north of Phyllis, and at mile 0.6 (1.0 km).	Lick Creek
03208000	Levisa Fork be- low Fishtrap Dam, near Millard, Ky.	Lat 37°25'33", long 82°24'45", Pike County, on right bank, 0.4 mi downstream from Fish- trap Dam, 1.1 mi upstream from Lower Pompey Branch, 1.9 mi northeast of Millard, 2.4 mi upstream from con- fluence with Russell Fork, and at mile 130.1.	Previously named maps
03210000	Johns Creek near Meta, Ky.	Lat 37°34'01", long 82°27'29", Pike County, on left bank, 10 ft downstream from bridge on U.S. Highway 119, 1,100 ft downstream from Ford Branch, 0.7 mi upstream from Raccoon Creek, 1.2 mi southwest of Meta, and at mile 42.7.	Belfry Lick Creek Matewan Meta Millard
03210040	Raccoon Creek near Zebu- lon, Ky.	Lat 37°30'55", long 82°27'05", Pike County, on right bank, adjacent to State Highway 1441, and 100 ft downstream from Chesapeake and Ohio Railroad bridge, 0.1 mi up- stream from unnamed tribu- tary, 1.5 mi southeast of Zebulon, and at mile 1.9.	Meta Millard

Table 8.--Locations of sampling stations in Levisa Fork
and Johns Creek drainage basins--continued

<u>USGS station number</u>	<u>Station name</u>	<u>Location</u>	<u>Basin on 7.5 minute topographic maps</u>
03210160	Caney Fork near Gulnare, Ky.	Lat 37°35'11", long 82°32'23", Pike County, on left bank, adjacent to State Highway 2061, 0.3 mi downstream from Cranesnest Branch, 0.4 mi upstream from Barn Branch, 2.9 mi south of Gulnare, and at mile 1.1.	Broad Bottom
03210310	Brushy Fork at Heenon, Ky.	Lat 37°39'58", long 82°29'03", Pike County, on right bank, adjacent to county road, 0.2 mi downstream from Left Fork, 0.9 mi upstream from Big Branch, and at mile 10.7.	Meta Varney
03210420	Buffalo Creek near Endi- cott, Ky.	Lat 37°37'58", long 82°36'18", Floyd County, adjacent to county road, 100 ft upstream from Clarks Branch, and 3.0 mi southeast of Endicott, and at mile 6.0.	Broad Bottom Thomas
03211500	Johns Creek near Van Lear, Ky.	Lat 37°44'37", long 82°43'27", Floyd County, on right bank, 100 ft upstream from Long Branch, 0.3 mi upstream from Daniels Creek, 0.7 mi down- stream from Dewey Dam, 2.5 mi southeast of Van Lear, and at mile 4.7.	Previously named maps

Table 9.--Summary of monthly discharges

03207800 Levisa Fork at Big Rock, Va.^{1/}

Drainage area 297 mi²

<u>Period</u>	<u>Water (ft³/s-days)</u>	<u>Sediment (tons)</u>
Aug., 1973	2,043	1,835.70
Sept.	926	386.30
Oct.	3,423	13,708.79
Nov.	17,538	92,909.00
Dec.	19,930	37,762.20
Jan., 1974	49,469	162,107.00
Feb.	18,429	8,511.00
Mar.	38,448	67,031.10
Apr.	20,200	12,788.80
May	14,606	11,623.10
June	13,985	121,595.50
July	3,186	489.30
Aug.	1,506	885.80
Sept.	1,993	1,664.90
Oct.	2,063	2,831.69
Nov.	4,672	4,134.37
Dec.	13,799	30,512.30
Jan., 1975	24,852	17,933.00
Feb.	25,872	20,773.60
Mar.	65,328	267,902.00
Apr.	23,821	30,037.00
May	20,305	18,152.00
June	3,947	5,896.00
July	1,957	2,353.00
Aug.	1,563	1,483.90
Sept.	2,841	5,928.85
Oct.	2,316	734.00
Nov.	4,765	5,582.40
Dec.	3,973	4,942.40
Total	407,756	952,495.00

Average daily discharge 462 ft³/s; 1,080 tons.

^{1/} Because of methods used in computations, the discharge values show a greater accuracy than that actually obtainable.

Table 9.--Summary of monthly discharges--continued

03207805 Conaway Creek at Conaway, Va.

Drainage area 7.40 mi²

<u>Period</u>	<u>Water (ft³/s-days)</u>	<u>Sediment (tons)</u>
Aug., 1974	141.6	461.23
Sept.	81.1	290.01
Oct.	99.5	763.12
Nov.	221.6	2,697.64
Dec.	344.3	1,230.95
Jan., 1975	546.1	944.59
Feb.	963.0	1,817.90
Mar.	1,891.0	13,962.20
Apr.	1,073.7	5,521.20
May	635.8	2,396.80
June	114.3	185.55
July	132.1	2,491.55
Aug.	88.9	4,263.84
Sept.	90.1	457.98
Oct.	114.4	248.37
Nov.	370.3	1,883.89
Dec.	144.1	2,424.98
Total	7,051.9	42,041.80

Average daily discharge 13.6 ft³/s; 81.2 tons.

Table 9.--Summary of monthly discharges--continued

03207845 Card Creek at Mouthcard, Ky.

Drainage area 4.18 mi²

<u>Period</u>	<u>Water (ft³/s-days)</u>	<u>Sediment (tons)</u>
Feb. 14, 1974 on	130.00	56.76
Mar.	570.10	2,617.90
Apr.	298.00	626.29
May	191.30	1,209.36
June	821.45	14,410.94
July	74.87	986.08
Aug.	103.13	2,027.61
Sept.	28.09	159.44
Oct.	109.60	1,091.08
Nov.	185.04	442.27
Dec.	225.40	629.75
Jan., 1975	272.80	387.41
Feb.	318.30	852.91
Mar.	1,053.20	8,684.67
Apr.	486.30	1,162.31
May	411.56	2,875.35
June	15.55	79.23
July	313.14	9,054.90
Aug.	50.35	699.56
Sept.	66.55	270.98
Oct.	58.45	306.78
Nov.	190.25	945.86
Dec.	-	-
Total	5,973.43	49,577.44

Average daily discharge 9.13 ft³/s; 75.8 tons.

Table 9.--Summary of monthly discharges--continued

03207875 Feds Creek at Fedscreek, Ky.

Drainage area 11.6 mi²

<u>Period</u>	<u>Water (ft³/s-days)</u>	<u>Sediment (tons)</u>
Nov. 20, 1973 on	800.10	1,192.92
Dec.	553.40	468.09
Jan., 1974	2,348.00	3,412.65
Feb.	565.20	40.12
Mar.	1,623.70	1,152.57
Apr.	1,117.00	188.18
May	934.60	263.27
June	1,218.00	1,684.09
July	151.40	55.45
Aug.	143.60	29.05
Sept.	115.20	31.34
Oct.	148.10	38.57
Nov.	297.20	161.91
Dec.	659.10	243.11
Jan., 1975	1,029.00	344.87
Feb.	1,176.00	420.08
Mar.	2,619.20	7,913.62
Apr.	648.10	250.78
May	585.3	203.97
June	125.3	58.29
July	78.4	71.49
Aug.	58.85	74.61
Sept.	65.79	24.19
Oct.	104.00	30.90
Nov.	195.90	164.56
Dec.	235.60	136.71
Total	17,596.04	18,655.39

Average daily discharge 22.8 ft³/s; 24.2 tons.

Table 9.--Summary of monthly discharges--continued

03207905 Big Creek at Dunlap, Ky.

Drainage area 9.55 mi²

<u>Period</u>	<u>Water (ft³/s-days)</u>	<u>Sediment (tons)</u>
Aug. 24, 1974 on	20.68	12.74
Sept.	95.10	50.20
Oct.	117.00	68.88
Nov.	299.90	137.18
Dec.	539.80	1,177.23
Jan., 1975	857.00	1,355.20
Feb.	1,000.00	761.86
Mar.	1,838.80	3,536.12
Apr.	818.00	340.98
May	897.00	480.46
June	204.60	102.55
July	160.00	351.34
Aug.	90.20	128.32
Sept.	69.67	91.00
Oct.	85.31	59.14
Nov.	163.50	418.72
Dec.	210.20	491.56
Total	7,466.76	9,563.48

Average daily discharge 15.1 ft³/s; 19.3 tons.

Table 9.--Summary of monthly discharges--continued

03207925 Island Creek near Phyllis, Ky.

Drainage area 2.42 mi²

<u>Period</u>	<u>Water (ft³/s-days)</u>	<u>Sediment (tons)</u>
Aug., 1974	50.14	690.23
Sept.	38.31	138.02
Oct.	33.63	846.70
Nov.	53.63	33.20
Dec.	146.60	514.44
Jan., 1975	255.90	292.84
Feb.	205.40	425.26
Mar.	612.70	1,156.60
Apr.	201.50	297.92
May	125.20	68.07
June	24.29	8.24
July	35.40	849.92
Aug.	9.27	22.78
Sept.	14.99	82.44
Oct.	43.58	103.03
Nov.	74.79	1,033.31
Dec.	42.52	44.85
Total	1,967.85	6,607.85

Average daily discharge 3.80 ft³/s; 12.8 tons.

Table 9.--Summary of monthly discharges--continued

03207935 Lick Creek at Lick Creek, Ky.

Drainage area 6.70 mi²

<u>Period</u>	<u>Water (ft³/s)-days)</u>	<u>Sediment (tons)</u>
Nov. 12, 1973 on	629.60	3,289.56
Dec.	373.40	919.32
Jan., 1974	1,265.60	5,589.00
Feb.	347.30	562.60
Mar.	945.20	4,020.60
Apr.	522.30	817.88
May	315.30	766.98
June	579.00	9,863.70
July	89.20	439.45
Aug.	88.30	474.77
Sept.	73.20	202.08
Oct.	95.20	177.06
Nov.	136.50	112.79
Dec.	291.40	761.90
Jan., 1975	481.20	1,488.70
Feb.	559.20	2,454.90
Mar.	1,341.40	10,700.10
Apr.	539.80	1,696.40
May	512.80	1,475.60
June	88.30	131.27
July	105.90	3,905.05
Aug.	40.62	94.60
Sept.	47.72	113.35
Oct.	72.28	52.82
Nov.	120.20	268.30
Dec.	129.50	317.71
Total	9,790.42	50,696.49

Average daily discharge 12.6 ft³/s; 65.0 tons.

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GEOLOGICAL SURVEY LOUISVILLE KY WATER RESOURCES DIV F/G 8/8
FLUVIAL SEDIMENT STUDY OF FISHTRAP AND DEWEY LAKES DRAINAGE BAS--ETC(U)
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USGS/WRD/WRI-78-037

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Table 9.--Summary of monthly discharges--continued

03207940 Millers Creek near Phyllis, Ky.

Drainage area 1.68 mi²

<u>Period</u>	<u>Water (ft³/s-days)</u>	<u>Sediment (tons)</u>
Jan., 1974	229.50	1,209.92
Feb.	96.30	747.20
Mar.	267.70	5,010.80
Apr.	105.00	1,341.00
May	166.60	8,911.00
June	184.99	14,922.96
July	10.58	13.89
Aug.	44.92	876.52
Sept.	28.46	1,615.67
Oct.	24.37	250.30
Nov.	33.46	184.03
Dec.	79.35	1,447.08
Jan., 1975	153.70	2,271.99
Feb.	125.78	1,885.30
Mar.	252.24	4,711.17
Apr.	105.02	2,251.59
May	89.35	818.94
June	20.94	129.08
July 25	143.14	19,941.86
Total	2,161.40	68,540.30

Average daily discharge 3.79 ft³/s; 120 tons.

Table 9.--Summary of monthly discharges--continued

03207965 Grapevine Creek at Phyllis, Ky.

Drainage area 6.20 mi²

<u>Period</u>	<u>Water (ft³/s-days)</u>	<u>Sediment (tons)</u>
Nov. 14, 1973 on	891.33	8,214.16
Dec.	398.20	189.34
Jan., 1974	1,320.70	2,689.95
Feb.	259.50	19.50
Mar.	1,092.80	2,875.52
Apr.	648.30	315.69
May	744.00	3,127.11
June	697.46	1,672.91
July	35.89	17.20
Aug.	61.16	63.97
Sept.	60.62	73.38
Oct.	38.72	20.27
Nov.	172.82	51.09
Dec.	488.40	222.76
Jan., 1975	612.20	433.10
Feb.	612.80	273.33
Mar.	1,663.10	1,803.70
Apr.	476.30	383.73
May	366.50	1,668.03
June	47.26	25.08
July	58.69	673.41
Aug.	20.95	8.67
Sept.	37.01	44.67
Oct.	97.32	32.40
Nov.	205.60	359.72
Dec.	208.00	504.13
Total	11,315.63	25,762.82

Average daily discharge 14.6 ft³/s; 32.2 tons.

Table 9.--Summary of monthly discharges--continued

03208000 Levisa Fork below Fishtrap Dam, Ky.

Drainage area 392 mi²

<u>Period</u>	<u>Water (ft³/s-days)</u>	<u>Sediment (tons)</u>
Oct., 1973	10,557	1,178.60
Nov.	15,840	37,721.80
Dec.	37,620	11,286.80
Jan., 1974	67,637	27,702.00
Feb.	26,206	4,975.60
Mar.	56,682	18,861.00
Apr.	17,087	2,557.70
May	24,362	4,731.60
June	23,756	5,516.60
July	4,858	366.50
Aug.	3,564	191.60
Sept.	3,139	178.10
Oct.	9,192	1,841.50
Nov.	12,540	3,800.40
Dec.	19,353	3,996.50
Jan., 1975	32,529	7,102.80
Feb.	36,238	9,263.70
Mar.	62,501	26,677.68
Apr.	48,355	16,357.40
May	26,385	5,283.40
June	5,850	441.30
July	3,984	237.70
Aug.	2,800	128.30
Sept.	6,316	747.00
Oct.	7,569	735.80
Nov.	12,278	5,145.60
Dec.	6,332	441.16
Total	583,038	197,468.14

Average daily discharge 709 ft³/s; 240 tons.

Table 9.--Summary of monthly discharges--continued

03210000 Johns Creek at Meta, Ky.

Drainage area 56.3 mi²

<u>Period</u>	<u>Water (ft³s-days)</u>	<u>Sediment (tons)</u>
July, 1974	419.8	367.28
Aug.	792.3	2,622.65
Sept.	882.8	518.86
Oct.	348.8	382.90
Nov.	1,102.8	901.84
Dec.	3,760.0	4,163.30
Jan., 1975	5,346.0	4,157.30
Feb.	5,927.0	5,970.70
Mar.	12,848.0	20,271.30
Apr.	4,343.0	10,498.30
May	3,846.0	5,086.80
June	568.9	404.01
July	797.8	24,882.47
Aug.	294.9	263.53
Sept.	529.2	2,695.57
Oct.	1,394.2	3,469.17
Nov.	2,642.0	36,772.76
Dec.	1,840.0	11,175.20
Total	47,683.5	134,603.94

Average daily discharge 86.9 ft³/s; 245 tons.

Table 9.--Summary of monthly discharges--continued

03210040 Raccoon Creek near Zebulon, Ky.

Drainage area 14.8 mi²

<u>Period</u>	<u>Water (ft³/s-days)</u>	<u>Sediment (tons)</u>
Oct., 1974	84.36	56.21
Nov.	396.90	356.04
Dec.	1,038.00	1,849.80
Jan., 1975	1,462.00	1,896.03
Feb.	1,344.00	1,121.30
Mar.	3,091.00	6,450.97
Apr.	858.30	682.71
May	872.90	2,002.58
June	107.90	112.54
July	110.55	493.16
Aug.	56.42	204.07
Sept.	137.35	285.97
Oct.	310.90	660.14
Nov.	513.10	2,939.11
Dec.	477.00	845.50
Total	10,860.68	19,956.13

Average daily discharge 23.8 ft³/s; 43.7 tons.

Table 9.--Summary of monthly discharges--continued

03210160 Caney Fork near Gulnare, Ky.

Drainage area 3.74 mi²

<u>Period</u>	<u>Water (ft³/s-days)</u>	<u>Sediment (tons)</u>
Oct., 1974	21.93	10.29
Nov.	47.59	12.73
Dec.	241.50	304.27
Jan., 1975	361.10	937.70
Feb.	477.50	999.51
Mar.	644.70	1,921.95
Apr.	131.40	640.39
May	244.90	1,292.89
June	36.92	208.22
July	21.18	564.53
Aug.	24.59	229.03
Sept.	45.09	904.31
Oct.	76.44	632.95
Nov.	124.00	1,631.18
Dec.	100.90	828.07
Total	2,599.74	11,118.02

Average daily discharge 5.69 ft³/s; 24.3 tons.

Table 9.--Summary of monthly discharges--continued

03210310 Brushy Fork at Heenon, Ky.

Drainage area 20.4 mi²

<u>Period</u>	<u>Water (ft³/s-days)</u>	<u>Sediment (tons)</u>
Oct., 1974	234.9	392.45
Nov.	480.6	192.41
Dec.	1,624.0	5,809.40
Jan., 1975	1,935.0	7,701.80
Feb.	1,932.0	13,221.70
Mar.	4,524.0	40,551.60
Apr.	1,889.0	13,332.10
May	1,916.0	25,921.70
June	450.9	2,581.75
July	305.4	7,808.66
Aug.	197.7	4,698.15
Sept.	750.7	13,842.51
Oct.	1,165.5	6,645.47
Nov.	1,502.0	17,891.20
Dec.	1,158.0	6,089.30
Total	20,065.70	166,680.20

Average daily discharge 43.9 ft³/s; 365 tons.

Table 9.--Summary of monthly discharges--continued

03210420 Buffalo Creek near Endicott, Ky.

Drainage area 6.21 mi²

<u>Period</u>	<u>Water (ft³/s-days)</u>	<u>Sediment (tons)</u>
Oct. 9, 1974	49.86	102.34
Nov.	162.34	40.38
Dec.	473.90	1,453.00
Jan., 1975	631.70	3,202.10
Feb.	583.60	4,528.50
Mar.	1,336.00	17,196.60
Apr.	511.70	4,566.14
May	981.40	11,739.02
June	122.79	190.34
July	70.15	101.26
Aug.	152.34	128.48
Sept.	99.02	287.00
Oct.	201.46	1,188.96
Nov.	325.16	6,509.24
Dec.	264.96	E800
Total	5,966.02	52,033.36

Average daily discharge 13.3 ft³/s; 116 tons.

Table 9.--Summary of monthly discharges--continued

03211500 Johns Creek near Van Lear, Ky.

Drainage area 206 mi²

<u>Period</u>	<u>Water (ft³/s-days)</u>	<u>Sediment (tons)</u>
Nov. 11-30, 1974	6,796	8,286.2
Dec.	14,106	13,915
Jan., 1975	19,878	14,913
Feb.	19,518	11,385
Mar.	31,769	23,127
Apr.	23,574	19,620
May	18,586	15,377
June	3,245	3,105
July	2,360	1,488.2
Aug.	1,504	924.6
Sept.	3,289	1,911.1
Oct.	5,331	1,754.7
Nov.	16,930	8,445.5
Dec.	7,792	3,671
Total	174,678	127,923.3

Average daily discharge 420 ft³/s; 307 tons.

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16. Abstracts <p>Fourteen drainage basins above Fishtrap and Dewey Lakes, and ranging in size from 1.68 to 297 mi² in eastern Kentucky and southeastern Virginia were studied to determine origin and magnitudes of sediment.</p> <p>Sediment yields from surface-mined area ranged from 2,890 to 21,000 tons/mi²/yr, and from 732 to 3,470 tons/mi²/yr from non-strip-mined areas.</p> <p>Water and sediment discharge from storms on surface-mined areas are similar to data from an earlier study in the Beaver Creek basin of Kentucky. Aerial photos are used to compare areas disturbed by surface and deep mining.</p> <p>Deposition rates and trap-efficiency figures are given.</p> <p>Chemical-quality studies indicate that man's activities have altered chemical quality of the water in Levisa Fork but not greatly affected the chemical quality of the water in Johns Creek basin.</p>			
17. Key Words and Document Analysis. 17a. Descriptors			
*Sediment load, *Sediment transport, *Sediment yield, *Sediment discharge, *Suspended load, *Erosion, Particle size, Sediment rates, Sedimentation, Trap efficiency, Sedimentology, Bicarbonates, Sulfates, Hardness (water), Strip-mine wastes, Coal mines.			
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